

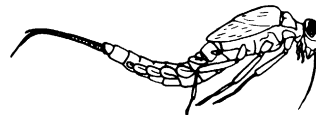
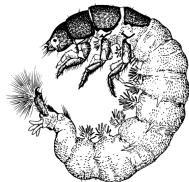
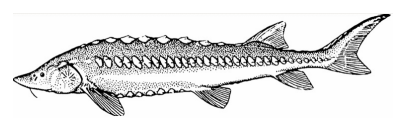
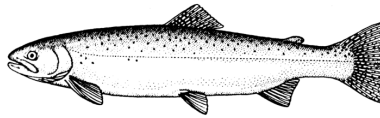
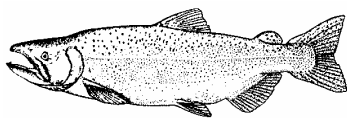
**IDENTIFICATION OF THE INSTREAM FLOW REQUIREMENTS FOR
ANADROMOUS FISH IN THE STREAMS WITHIN THE CENTRAL VALLEY
OF CALIFORNIA AND FISHERIES INVESTIGATIONS**

**Annual Progress Report
Fiscal Year 2013**

U.S. Fish and Wildlife Service
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Prepared by staff of
The Restoration and Monitoring Program



PREFACE

The following is the Twelfth Annual Progress Report, Identification of the Instream Flow Requirements for Anadromous Fish in the Streams within the Central Valley of California and Fisheries Investigations, prepared as part of the Central Valley Project Improvement Act (CVPIA) Instream Flow and Fisheries Investigations, an effort which began in October, 2001.¹ Title 34, Section 3406(b)(1)(B) of the CVPIA, P.L. 102-575, requires the Secretary of the Department of the Interior to determine instream flow needs for anadromous fish for all Central Valley Project controlled streams and rivers, based on recommendations of the U.S. Fish and Wildlife Service (Service) after consultation with the California Department of Fish and Wildlife (CDFW). The purposes of this investigation are: 1) to provide scientific information to the Service's CVPIA Program to be used to develop such recommendations for Central Valley streams and rivers; and 2) to provide scientific information to other CVPIA programs to use in assessing fisheries restoration actions. The purpose of this report is to provide an update on the Monitoring and Restoration Program's CVPIA-funded activities and accomplishments during the last fiscal year to interested stakeholders. An in-depth presentation on the instream flow studies is given in the final reports for these studies. The annual reports serve as final reports for the fisheries investigation tasks.

The field work described herein was conducted by Ed Ballard, Mark Gard, Rick Williams, Harry Kahler and John Henderson.

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Electronic versions of our final reports and previous years' annual reports are available on our website:

http://www.fws.gov/sacramento/Fisheries/Instream-Flow/fisheries_instream-flow_reports.htm

¹ The scope of this program was broadened in FY 2009 to include fisheries investigations. This program is a continuation of a 7-year effort, titled the Central Valley Project Improvement Act Instream Flow Investigations, which ran from February 1995 through September 2001.

OVERVIEW

In response to substantial declines in anadromous fish populations, the Central Valley Project Improvement Act provided for enactment of all reasonable efforts to double sustainable natural production of anadromous fish stocks including the four races of Chinook salmon (fall, late-fall, winter, and spring), steelhead trout, white and green sturgeon, American shad and striped bass. In June 2001, the Service's Sacramento Fish and Wildlife Office, Energy Planning and Instream Flow Branch prepared a study proposal to use the Service's Instream Flow Incremental Methodology (IFIM) to identify the instream flow requirements for anadromous fish in selected streams within the Central Valley of California. The proposal included completing instream flow studies on the Sacramento and Lower American Rivers and Butte Creek which had begun under the previous 7-year effort, and conducting instream flow studies on other rivers, with the Yuba River selected as the next river for studies. In 2004, Clear Creek was selected as an additional river for studies. In 2007, the Tuolumne River was selected for a minor project to quantify floodplain inundation area as a function of flow. In 2008, South Cow Creek was selected as an additional river for studies. In 2010, the Stanislaus River was selected to perform activities to assist the Bureau of Reclamation with conducting an instream flow study. The last report for the Lower American River study was completed in February 2003, the final report for the Butte Creek study was completed in September 2003, the last two reports for the Sacramento River were completed in December 2006, the final report for the Tuolumne River was completed in September 2008, the reports for the Yuba River were completed in December 2010, the final report for the South Cow Creek study was completed in July 2011, and the Stanislaus River hydraulic and habitat modeling was completed in FY 2012.

In 2013, the following fisheries investigation tasks were selected for study: 1) Clear Creek biovalidation – how well does IFIM compare to field observations; 2) American River gravel placement monitoring; 3) Stanislaus River floodplain area versus flow; 4) Stanislaus River floodplain restoration project monitoring; 5) Tuolumne River Bobcat Flat monitoring; 6) Sacramento River green sturgeon spawning habitat suitability criteria data collection; 7) Clear Creek inSALMO modeling; 8) Yuba River Hammon Bar restoration project monitoring; 9) Yuba River Daguerre Alley restoration project monitoring; 10) Cottonwood Creek baseline habitat assessment; 11) Cottonwood Creek geomorphic data collection; 12) Antelope Creek geomorphic monitoring and 13) Antelope Creek Bridge as-built survey.

The Clear Creek study was planned to be a 5-year effort, beginning in October 2003. The goals of the study are to determine the relationship between stream flow and physical habitat availability for all life stages of Chinook salmon (fall- and spring-run) and steelhead/rainbow trout. There are four phases to this study based on the life stages to be studied and the number of segments delineated for Clear Creek from downstream of Whiskeytown Reservoir to the

confluence with the Sacramento River². The four phases are: 1) spawning in the upper two segments; 2) fry and juvenile rearing in the upper two segments; 3) spawning in the lower segment; and 4) fry and juvenile rearing in the lower segment. Field work for the above four phases was completed in FY 2005, FY 2007, FY 2008 and FY 2009, respectively. In FY 2007 the final report and the peer review response-to-comments document for spawning in the upper two segments was completed. In FY 2011, with funding from the CVPIA Clear Creek program, final reports and the peer and stakeholder review response-to-comments documents for rearing in the upper two segments and spawning in the lower segment were completed. In FY 2013, we completed a final report for rearing in the lower segment and conducted peer and stakeholder reviews of this report. An additional task, preparing a document that provides a synthesis of all four reports, was added in FY 2011. The synthesis report will be completed in FY 2014.

Work on the fisheries investigations tasks, to provide scientific information to other CVPIA programs to use in assessing fisheries restoration actions, in FY 2013 was as follows:

- 1) We completed biological verification of study sites 3A and 3B on Clear Creek.
- 2) In FY 2013, with funding from the CVPIA b(13) program, we conducted modeling of the FY 2010, 2011 and 2012 gravel restoration projects on the American River and assisted with the design for the FY 2013 gravel restoration project. This activity will not be continued in FY 2014 due to lack of funding.
- 3) We completed the remaining phases of the Stanislaus River floodplain area versus flow task in FY 2013 with funding from AFRP³.
- 4) We collected topographic data and ground-truthed LIDAR data for the Stanislaus River Button Bush project. In FY 2014, we will be identifying additional Stanislaus River floodplain restoration projects using the results of the Stanislaus River floodplain model.
- 5) We completed modeling pre- and post-restoration habitat to determine the quantity of fall-run Chinook salmon and steelhead spawning and rearing habitat created by the Bobcat Flat project.
- 6) We collected habitat suitability criteria data for green sturgeon spawning for six locations on the Sacramento River.
- 7) We provided high flow simulations to be used in the inSALMO software as applied to Clear Creek.
- 8) We modeled the amount of fall-run Chinook salmon and steelhead rearing habitat created by the pilot phase of the Yuba River Hammon Bar restoration project. We will be collecting data and conducting modeling on the second phase of the Yuba River Hammon Bar restoration project in FY 2014.

² There are three segments: the upper alluvial segment, the canyon segment, and the lower alluvial segment. Spring-run Chinook salmon spawn in the upper two segments, while fall-run Chinook salmon spawn in the lower segment and steelhead/rainbow trout spawn in all three segments.

³ The first phase was conducted in FY 2011 with funding from the Comprehensive Assessment and Monitoring Program.

- 9) We started collecting data to model the amount of fall-run Chinook salmon and steelhead rearing habitat created by the proposed Yuba River Daguerre Alley restoration project. We will be completing data collection and conducting the modeling for this effort in FY 2014.
- 10) We completed data collection and modeling to quantify the amount of fall-run Chinook salmon and steelhead rearing habitat in Cottonwood Creek as a baseline assessment.
- 11) We finished collecting additional topographic data for the first year's transects used in task 10 to assess topographic changes at these cross-sections.
- 12) We completed a hydraulic model of the flow split in Antelope Creek.
- 13) We completed an as-built topographic survey of the Antelope Creek bridge crossing restoration project. We will conduct another topographic survey in FY 2014 to assess effects of high flow on the restoration project.

The following sections summarize project activities between October 2012 and September 2013.

CLEAR CREEK

Habitat Simulation

Fall-run Chinook salmon and steelhead/rainbow trout rearing (Lower Alluvial Segment)

In FY 2013, we issued a final report on fall-run and spring-run Chinook salmon and steelhead/rainbow trout rearing habitat in the Lower Alluvial Segment.

Synthesis Report

In FY 2012, we completed a draft synthesis report. We were not able to make any progress on this report in FY 2013 due to Red Bluff staff time limitations. We will be issuing a final report in FY 2014.

FISHERIES INVESTIGATIONS

Clear Creek Biovalidation

Methods

This task had the following six subtasks: 1) compare 2008 juvenile habitat use to juvenile Combined Suitability Index (CSI); 2) compare 2005 juvenile habitat use to juvenile CSI; 3) compare 2007 Spawning Area Mapping (SAM) to adult CSI; 4) compare 2008 SAM to adult CSI; 5) after building fall-run Chinook salmon adult criteria from unoccupied locations in model, rerun earlier analysis comparing SAM and CSI; and 6) review statistical approach for these. The juvenile habitat use and spawning area mapping data were supplied by the Red Bluff Fish and Wildlife Office. Discussions during FY 2009 narrowed the scope of this work to examining data from restoration sites 3A and 3B. CSI values for site 3B were computed from

the River2D model developed for the Clear Creek IFIM study. CSI values for site 3A were computed from a River2D model that was developed using: 1) bed topography data previously collected by Graham Matthews and Associates; 2) substrate and cover polygon mapping that the Energy Planning and Instream Flow Branch conducted in FY 2009; and 3) transect data collected by the Energy Planning and Instream Flow Branch in FY 2009.

Since restoration site 3B was constructed in 2007, we used SAM data from 2008 through 2010 for the spawning validation. From this data, we used the redds located in the two-dimensional hydraulic and habitat models of restoration sites 3A and 3B. Since we had established these sites based on State Plane coordinates, we were able to convert the redd locations to local coordinates by just subtracting given numbers from the State Plane coordinates. For the spawning area mapping, we determined how many redds were in each mapped polygon by dividing the area of the polygon by 211 ft²/redd and then equally spaced points for that many redds in each polygon, using GIS⁴. We compared the combined habitat suitability predicted by RIVER2D at each fall-run Chinook salmon redd location to that at unoccupied locations in the restoration sites 3A and 3B. We ran the RIVER2D cdg files at the average flows for the period from the start of the spawning season up to the date of SAM data collection (October 1 – December 4, 2008, October 1 – December 3, 2009, and October 1 – December 1, 2010) to determine the combined habitat suitability at individual points for RIVER2D. We used a random number generator to select 200 locations without redds in each site in each year. Locations were eliminated that: 1) were less than 3 feet (0.91 m) from a previously-selected location; 2) were within the SAM polygons, with a one-foot buffer; 3) were located in the dry part of the site; and 4) were not located in the site (between the upstream and downstream transects). We used one-tailed Mann-Whitney U tests (Zar 1984) to determine whether the combined suitability predicted by RIVER2D was higher at redd locations versus locations where redds were absent.

For rearing, snorkel survey data consisted of the number of fish < 50 mm and > 50 mm SL in each mesohabitat unit for multiple survey dates in 2008 and 2010. In addition, for 2008 we were supplied with polygons of hotspots, which had high fry and juvenile fish densities; actual fish counts were not made for the hotspots. We ran the RIVER2D cdg files at the average flows for the dates when the snorkel surveys were conducted and computed the amount of weighted useable area for each mesohabitat unit, for the hotspots combined, and for the entire site. We used a linear regression with a constant of zero to test whether there was a significant relationship between the average number of fish < 50 mm and > 50 mm SL seen in each mesohabitat unit and the amount of weighted useable area for fall-run Chinook salmon fry and juvenile rearing in each mesohabitat unit. We did separate analyses for 2008 and 2010 because fish numbers were much higher in 2008 (average of 4,822 fry and 1,011 juveniles) as compared to 2010 (average of 1,075 fry and 156 juveniles). We also compared the proportion of weighted useable area in the hotspots, as compared to the entire site, to the proportion of the area of the hotspots, as compare to the entire site. Our hypothesis was that the proportion of weighted

⁴ 211 ft²/redd was the average area of single-redd fall-run Chinook salmon polygons in 2003 on Clear Creek.

useable area in the hotspots should be much greater than the proportion of the area of the hotspots in the study sites if fish were preferentially selecting the hotspots. We were unable to statistically test this hypothesis due to small sample size ($n = 2$).

Results

The combined habitat suitability predicted by the 2-D model (Figure 1) was significantly higher for locations with redds (median = 0.56, $n = 712$) than for locations without redds (median = 0.36, $n = 1200$), based on the Mann-Whitney U test ($U = 290,582$, $p < 0.000001$). A greater number in the suitability index indicates greater suitability. The 2-D model predicted that 37 of the 712 (5.2%) redd locations had a combined suitability of zero. Twenty two of these locations, including all of the locations that River2D predicted were dry, were from Site 3B in 2010. Fourteen redd locations had a combined suitability of zero due to River2D predicting that the location was dry, eight had a combined suitability of zero due to the predicted substrate being too small (substrate code of 0.1), 12 had a combined suitability of zero due to the predicted depth being too low (depth less than 0.5 foot (0.15 m)), and three had a combined suitability of zero due to the predicted velocity being too low (velocity less than 0.10 ft/s (0.03 m/s)).

There were significant linear relationships between the average number of fish < 50 mm SL and the weighted useable area for fry in each mesohabitat unit for both 2008 ($r^2 = 0.37$, $p < 0.00001$) and 2010 ($r^2 = 0.52$, $p < 0.00001$, Figure 2), and between the average number of fish > 50 mm SL and the weighted useable area for juveniles in each mesohabitat unit for both 2008 ($r^2 = 0.33$, $p < 0.00001$) and 2010 ($r^2 = 0.51$, $p < 0.00001$, Figure 3). The proportion of weighted usable area for fry (2.02%) and juveniles (1.77%) in the hotspots was 67 to 91 percent higher than the proportion of the area of the hotspots (1.06%) of restoration sites 3A and 3B.

The sixth subtask was completed in FY 2009 by Western Ecosystems Technology, Inc. under a Cooperative Agreement funded by the Energy Planning and Instream Flow Branch. Results of that subtask are presented in our FY 2009 annual report.

Discussion

The relatively high combined suitability of unoccupied locations reflects the design of the restoration projects to create high-quality spawning habitat and the low numbers of spawners in 2008 through 2010, relative to the availability of spawning habitat in Clear Creek. The weak performance of River2D in predicting the combined suitability of redd locations in restoration site 3B in 2010 was likely due to channel migration as a result of a peak flow of 3,400 cfs on January 20, 2010 (Pittman and Matthews 2012). One of the basic assumptions of River2D is a fixed bed. Biological validation of a site with bed topography that changes over time would require additional data collection and hydraulic and habitat modeling after the channel changes to accurately reflect the hydraulic and habitat conditions that existed at the time of the collection of the biological validation data. Despite these challenges, the successful biological verification increases the confidence in the use of the Clear Creek flow-habitat relationships for fisheries management in Clear Creek.

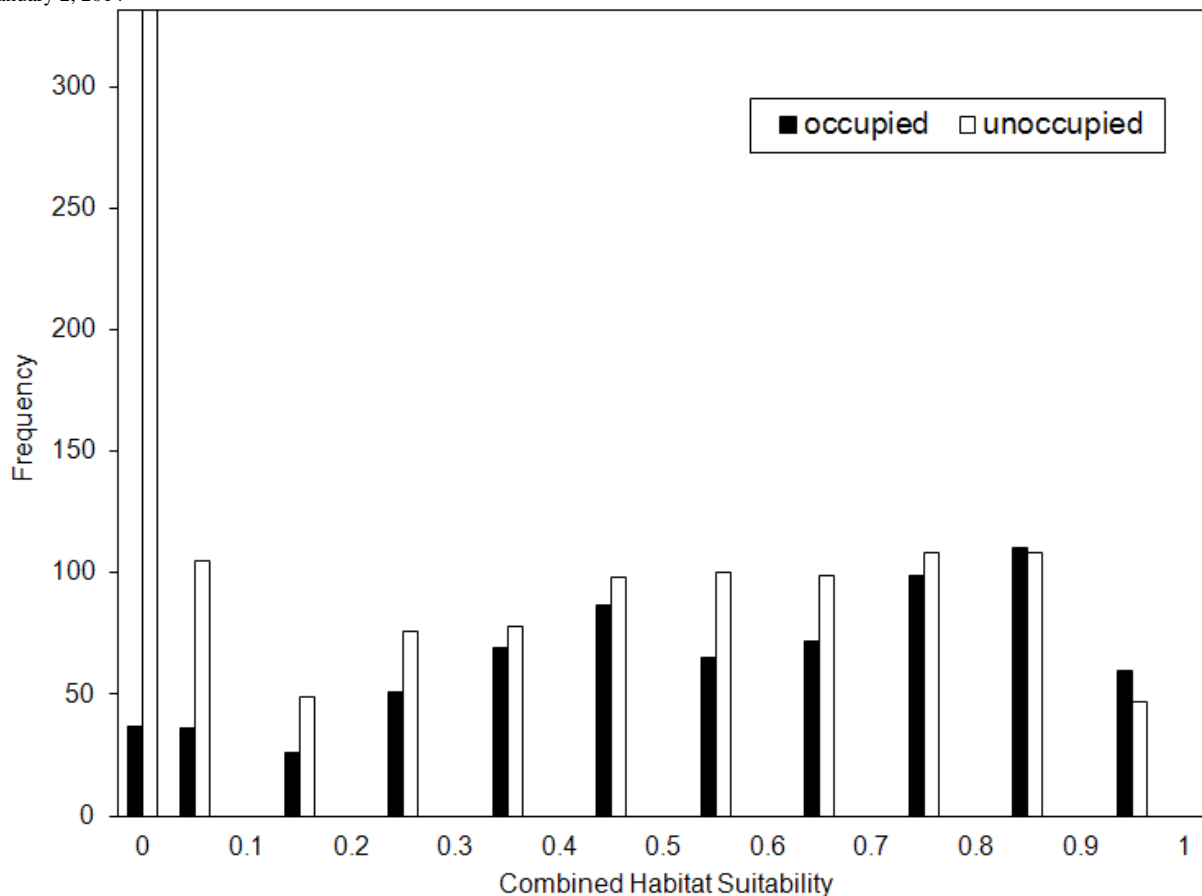


Figure 1. Combined suitability for 2-D model locations with (occupied) and without (unoccupied) fall-run Chinook salmon redds. The median combined suitability for occupied and unoccupied locations was, respectively, 0.56 and 0.36. Frequency is the number of occupied or unoccupied locations.

American River Gravel Placement Monitoring

Methods

The purpose of this task was to collect data to develop hydraulic and habitat models of sites where gravel was placed in the American River above Sunrise Bridge in 2010 and 2011, at Lower Sailor Bar in 2012, and at River Bend in 2013. The purpose of the models is to quantify the amount of spawning and rearing habitat that was created by the restoration projects. The post-restoration topography data for the 2010 site was also used to design the 2011 gravel placement site, while the pre-restoration data for Lower Sailor Bar was used to design the 2012 gravel placement site, and the pre-restoration data for River Bend was used to design the 2013 gravel placement site. High flows in 2006 resulted in downcutting of the main stream river channel at the upstream end of an island downstream of the 2010 site. As a result, a side channel that used to flow at a total American River flow of 800 cfs no longer had flow until the total American River flow reached an estimated 3,200 cfs. The 2010 and 2011 gravel placement

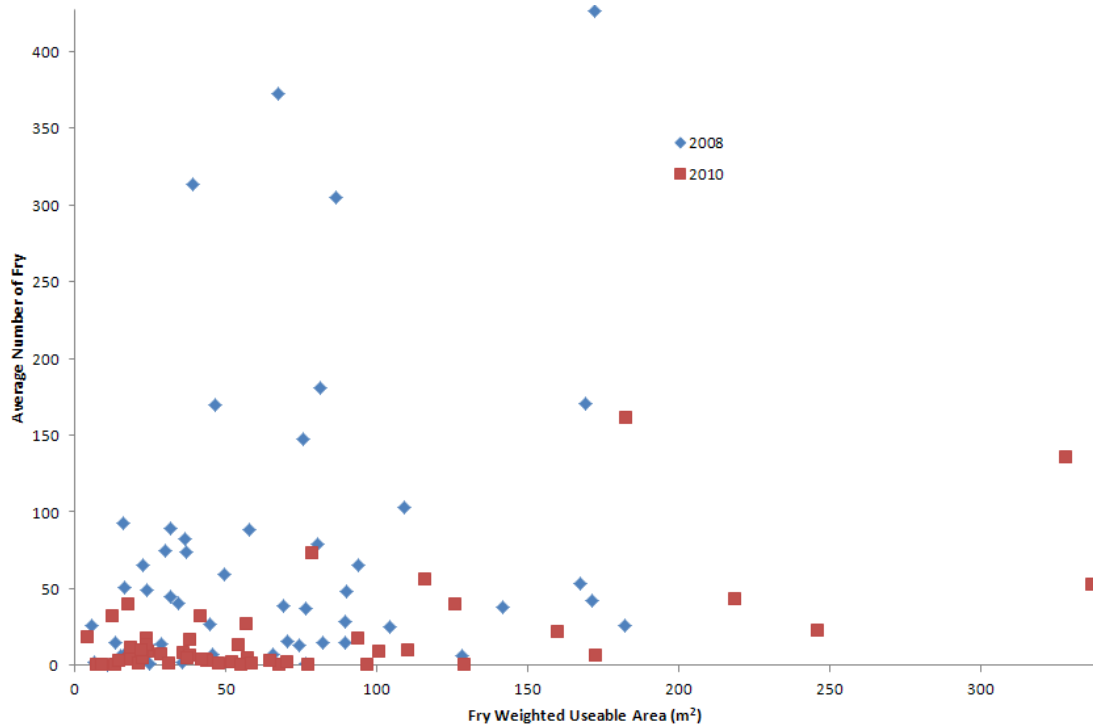


Figure 2. Average number of fish < 50 mm SL in each mesohabitat unit versus the weighted useable area for fry in each mesohabitat unit

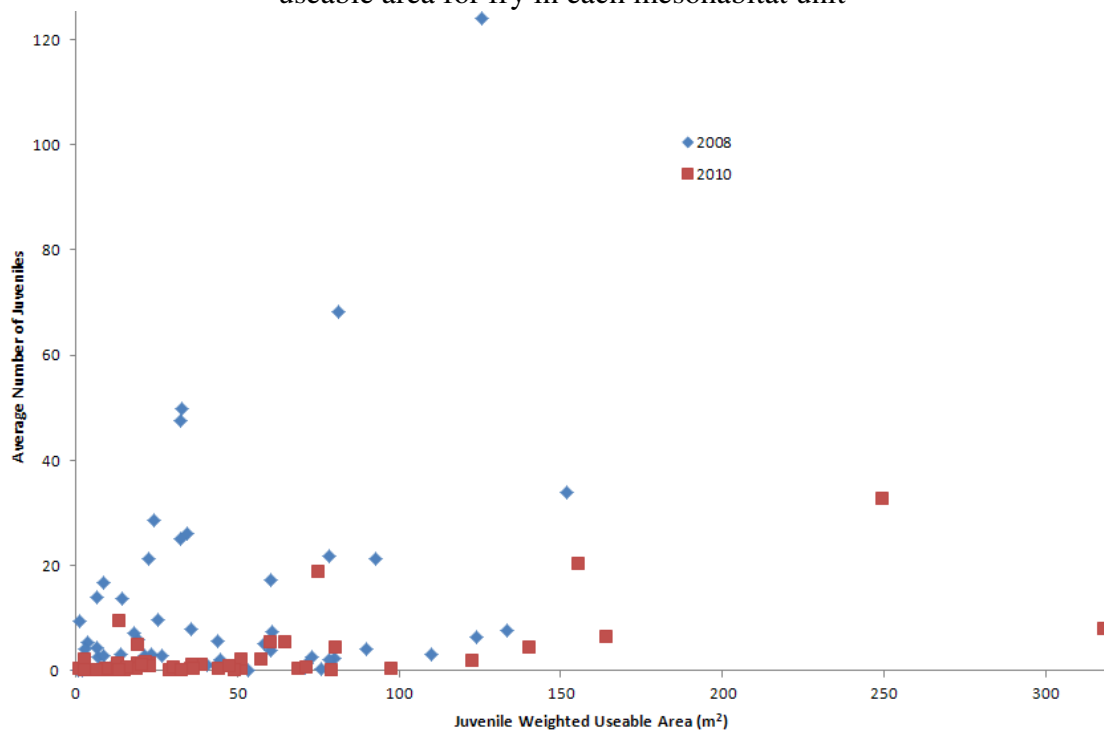


Figure 3. Average number of fish > 50 mm SL in each mesohabitat unit versus the weighted useable area for juveniles in each mesohabitat unit

designs consisted of both placement of spawning-sized material upstream of the island to create spawning habitat, and placement of larger material in the downcut main channel location to raise the water surface at this location, so that the side channel would once again flow at lower American River flows. We used topographic, substrate and cover data we collected in FY 2010 at the placement locations, together with the remaining topographic data collected in FY 2011, to develop pre-restoration hydraulic and habitat models to quantify how much spawning and rearing habitat was created by the 2010 gravel placement.

A PHABSIM transect was placed at the upstream and downstream end of each study site. The downstream transect was modeled with PHABSIM to provide water surface elevations as an input to the 2-D model. The upstream transect was used in calibrating the 2-D model - bed roughnesses are adjusted until the water surface elevation at the top of the site matches the water surface elevation predicted by PHABSIM. Transect pins (headpins and tailpins) were marked on each river bank above the 7,000 cfs water surface level using rebar driven into the ground and/or lag bolts placed in tree trunks. Survey flagging was used to mark the locations of each pin. Vertical benchmarks were established at each site to serve as the vertical elevations to which all elevations (streambed and water surface) were referenced. Vertical benchmarks consisted of lag bolts driven into trees. In addition, horizontal benchmarks (rebar driven into the ground) were established at each site to serve as the horizontal locations to which all horizontal locations (northings and eastings) were referenced. The precise northing and easting coordinates and vertical elevations of two horizontal benchmarks were established for each site using survey-grade Real Time Kinematic (RTK) Global Positioning System (GPS). The elevations of these benchmarks were tied into the vertical benchmarks on our sites using differential leveling. The data collected on the upstream and downstream transect included: 1) water surface elevations (WSELs), measured to the nearest 0.01 foot (0.003 m) at a minimum of three significantly different stream discharges using standard surveying techniques (differential leveling); 2) wetted streambed elevations determined by subtracting the measured depth from the surveyed WSEL at a measured flow; 3) dry ground elevations to points above bank-full discharge surveyed to the nearest 0.1 foot (0.031 m); 4) mean water column velocities measured at a mid-to-high-range flow at the points where bed elevations were taken; and 5) substrate and cover classification (Tables 1 and 2) at these same locations and also where dry ground elevations were surveyed.

Topographic data between the upstream and downstream boundaries of the 2010, 2011, 2012 and 2013 gravel placement sites were collected using survey-grade RTK GPS units or a robotic total station and stadia rod for the dry and shallow portions of the sites, and with a combination of an Acoustic Doppler Current Profiler (ADCP) and a survey-grade RTK GPS unit for the deeper portions. For each traverse with the ADCP, the RTK GPS was used to record the horizontal location and WSEL at the starting and ending location of each traverse, while the ADCP provided depths and distances across the traverse. The WSEL of each ADCP traverse is then used together with the depths from the ADCP to determine the bed elevation of each point along the traverse. For the 2010 and 2011 sites, we used the same method downstream of the downstream boundary to determine the stage of zero flow for the downstream transect. We also collected substrate and cover data for each topographic point collected with the survey-grade RTK GPS unit or total station and stadia rod, and mapped in substrate and cover polygons for the

Table 1
Substrate Descriptors and Codes

Code	Type	Particle Size (inches)
0.1	Sand/Silt	< 0.1
1	Small Gravel	0.1 – 1
1.2	Medium Gravel	1 – 2
1.3	Medium/Large Gravel	1 – 3
2.3	Large Gravel	2 – 3
2.4	Gravel/Cobble	2 – 4
3.4	Small Cobble	3 – 4
3.5	Small Cobble	3 – 5
4.6	Medium Cobble	4 – 6
6.8	Large Cobble	6 – 8
8	Large Cobble	8 – 10
9	Boulder/Bedrock	> 12
10	Large Cobble	10 – 12

areas sampled with the ADCP; the vertices of these polygons were recorded with the survey-grade RTK GPS unit. The RTK GPS and total station data had an accuracy of 0.1 foot horizontally and vertically.

The topographic data for the 2-D model (contained in bed files) is first processed using the R2D_Bed software, where breaklines are added to produce a smooth bed topography. The resulting data set is then converted into a computational mesh using the R2D_Mesh software, with mesh elements sized to reduce the error in bed elevations resulting from the mesh-generating process to 0.1 foot where possible, given the computational constraints on the number of nodes. The resulting mesh is used in River2D to simulate depths and velocities at the flows to be simulated. The Physical Habitat Simulation (PHABSIM) transect at the outflow end of each site is calibrated to provide the water surface elevation (WSEL) at the outflow end of the site used by River2D. The PHABSIM transect at the inflow end of the site is calibrated to provide the water surface elevations used to calibrate the River2D model. The initial bed roughnesses used by River2D are based on the observed substrate sizes and cover types (Tables 1 and 2). A multiplier is applied to the resulting bed roughnesses, with the value of the multiplier adjusted so that the WSEL generated by River2D at the inflow end of the site match the WSEL predicted by

Table 2
Cover Coding System

Cover Category	Cover Code
No cover	0.1
Cobble	1
Boulder	2
Fine woody vegetation (< 1" diameter)	3
Fine woody vegetation + overhead	3.7
Branches	4
Branches + overhead	4.7
Log (> 1' diameter)	5
Log + overhead	5.7
Overhead cover (> 2' above substrate)	7
Undercut bank	8
Aquatic vegetation	9
Aquatic vegetation + overhead	9.7
Rip-rap	10

the PHABSIM transect at the inflow end of the site⁵. The River2D model is run at the flows at which the validation data set was collected, with the output used to determine the difference between simulated and measured velocities, depths, bed elevations, substrate and cover. The River2D model is also run at the simulation flows to use in computing habitat. Spawning habitat was generated using habitat suitability criteria from the American River, while rearing habitat was generated using the habitat suitability criteria developed for the Yuba River.

Results

In FY 2013, we completed collection of the remaining pre-restoration data for the 2012 site (some topography in the upstream extension and south bank floodplain), all of the post-restoration data for the 2012 site, and all of the pre-restoration data for the 2013 site, with the

⁵ This is the primary technique used to calibrate the River2D model.

exception of some vegetated areas which were not within the footprint of the 2013 project but were needed to develop the hydraulic and habitat models for the pre-restoration 2013 site. We completed development and calibration of hydraulic models for the post-restoration 2011 site and pre-restoration 2012 site, and production runs for the 2010 and pre-restoration 2011 sites in FY 2013. Due to the lack of b(13) funding in FY 2014, we will not be able to develop hydraulic and habitat models for the 2013 site. We expect to complete pre- and post-restoration hydraulic modeling for the post-restoration 2011 and pre and post-restoration 2012 sites in FY 2014, with results to be presented in our FY 2014 annual report. Pre and post-restoration habitat for the 2010 site is shown in Figures 4 through 9.

Discussion

The habitat effects of the 2010 project varied with flow, life stage and species, reflecting differing habitat requirements and changes in hydraulic conditions with flow. The 2010 project had the biggest benefit for spawning for flows less than 5,000 cfs, reflecting the focus of the project on creating spawning habitat and the design flow for the restoration project of 2,000 cfs. In general, the habitat benefits of the project can be tied to the three main hydraulic and structural effects of the project, namely rewetting the side channel at a lower flow, increasing the stage at a given flow in the upstream portion of the site, and adding additional spawning gravel. At flows greater than 5,000 cfs, the side channel already had flow prior to the restoration project, and the increased side channel flows at these higher flows after construction of the restoration project results in velocities in the side channel that were higher than optimal velocities for spawning. The effect of the restoration project on fry habitat, increasing it for fall-run Chinook salmon but decreasing it for steelhead at most flows, likely reflects the different habitat requirements for these two species, with steelhead having a much higher preference for cobble, large amounts of which were replaced by spawning gravel as a result of the restoration project. The decreased amount of juvenile rearing habitat at higher flows likely reflects velocities in the side channel becoming too fast. At lower flows, the increase in juvenile habitat is likely due to rewetting of the side channel at flows less than 3,200 cfs, as a result of project construction.

Stanislaus River Floodplain Versus Flow Relationships

Methods

The goal of this task was to develop two-dimensional hydraulic models to quantify the relationship between floodplain area and flow for the following four reaches of the Stanislaus River: 1) mouth of Stanislaus River to Ripon; 2) Ripon to Jacob Meyers; 3) Jacob Meyers to Orange Blossom; and 4) Orange Blossom to Knight's Ferry (Figure 10), for flows ranging from 250 to 5,000 cfs. Light Detection and Ranging (LIDAR) and Sound Navigation and Ranging (SONAR) data collected for the Stanislaus River instream flow study was used as the topographic data source for the hydraulic model. The first step in developing the topographic input for the model was to georeference in Arc Map (ESRI, Redlands, CA) digital aerial photos

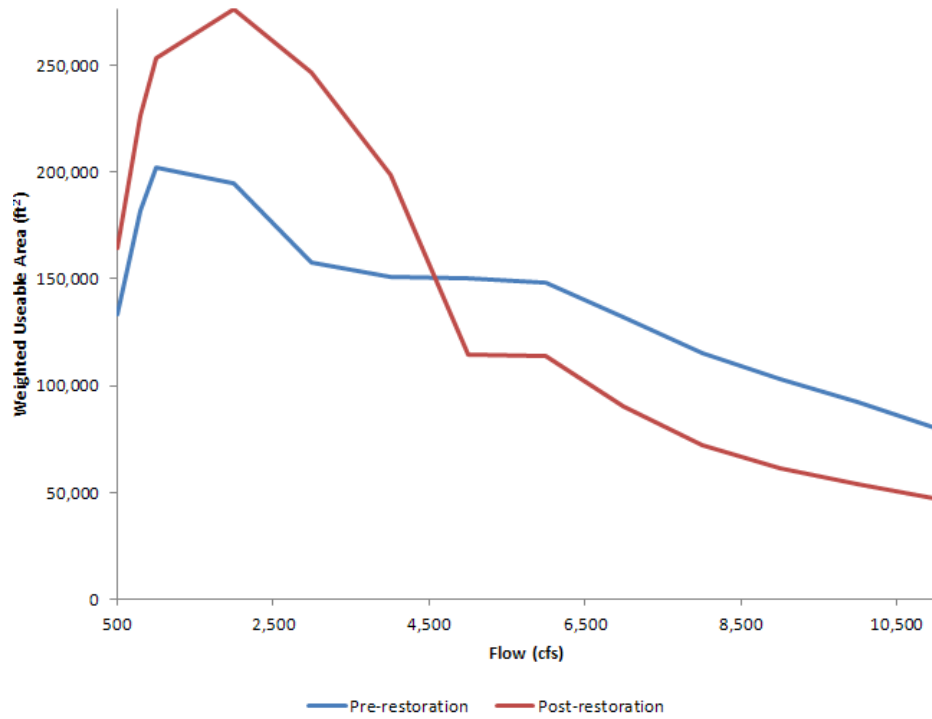


Figure 4

Above Sunrise fall-run Chinook salmon spawning flow-habitat relationships before and after construction of the 2010 site

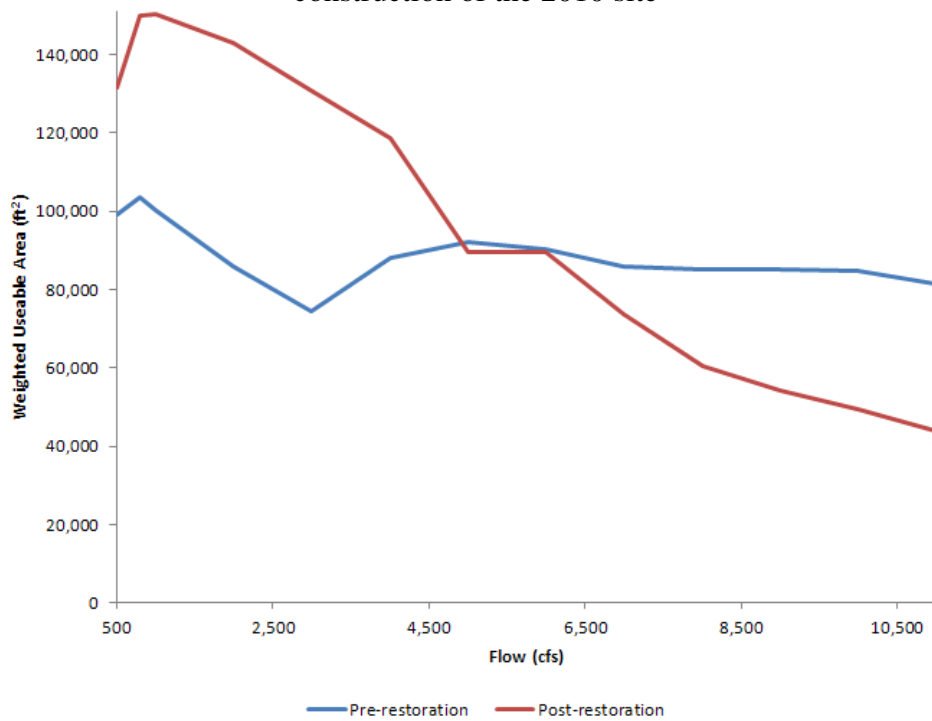


Figure 5

Above Sunrise steelhead spawning flow-habitat relationships before and after construction of the 2010 site

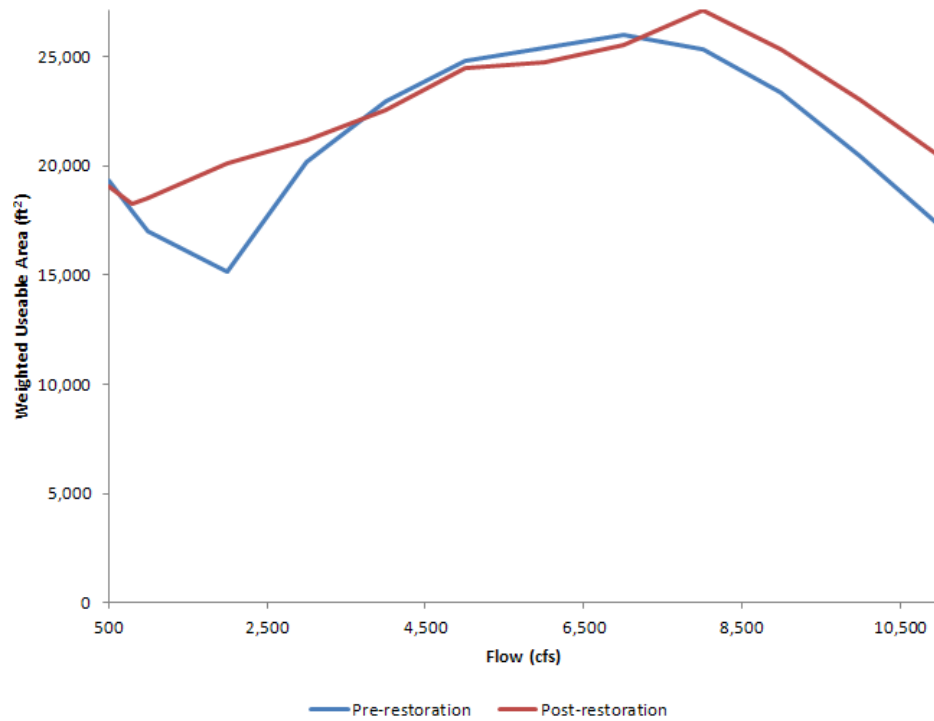


Figure 6

Above Sunrise fall-run Chinook salmon fry rearing flow-habitat relationships before and after construction of the 2010 site

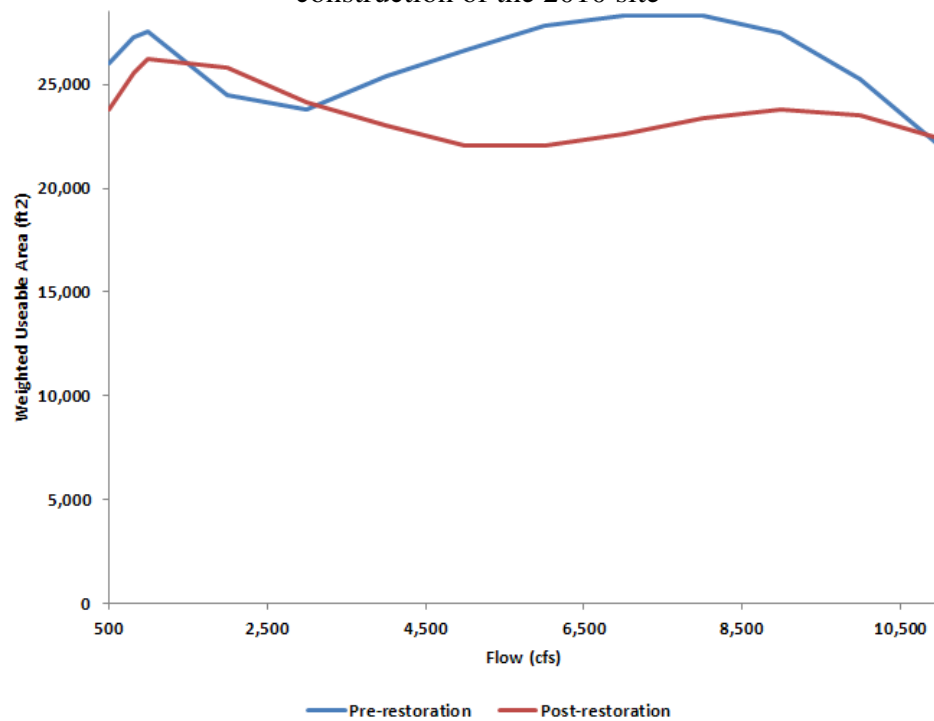


Figure 7

Above Sunrise steelhead fry rearing flow-habitat relationships before and after construction of the 2010 site

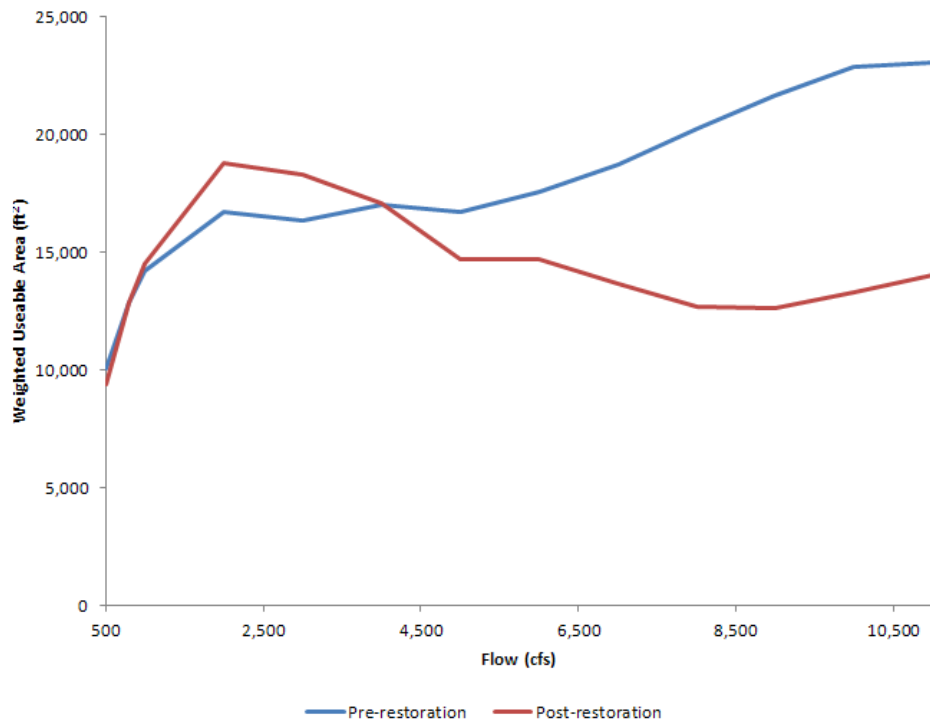


Figure 8

Above Sunrise fall-run Chinook salmon juvenile rearing flow-habitat relationships before and after construction of the 2010 site

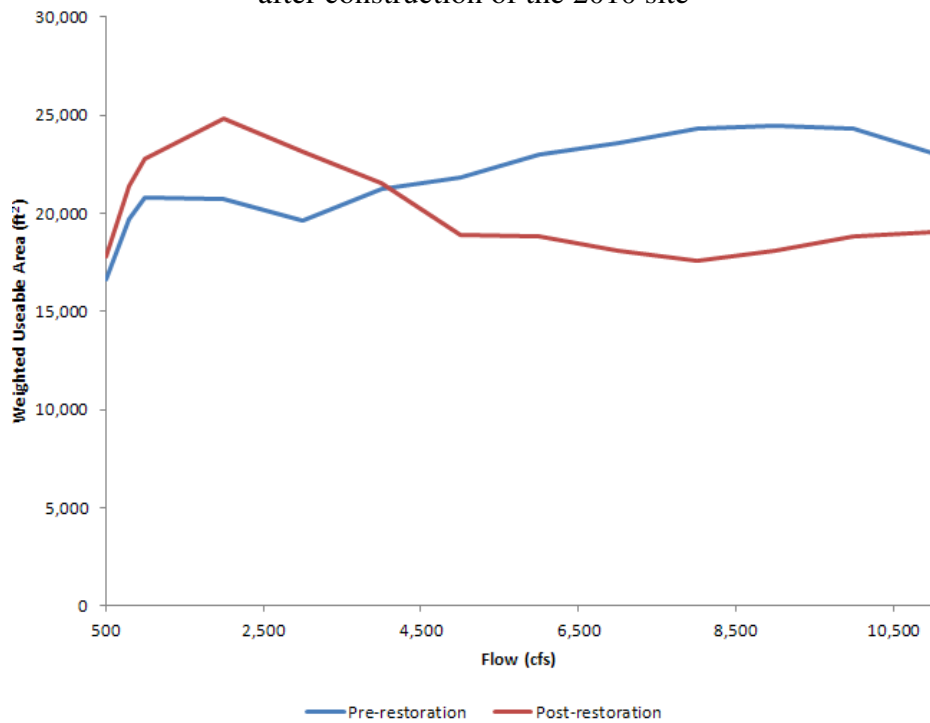


Figure 9

Above Sunrise steelhead juvenile rearing flow-habitat relationships before and after construction of the 2010 site

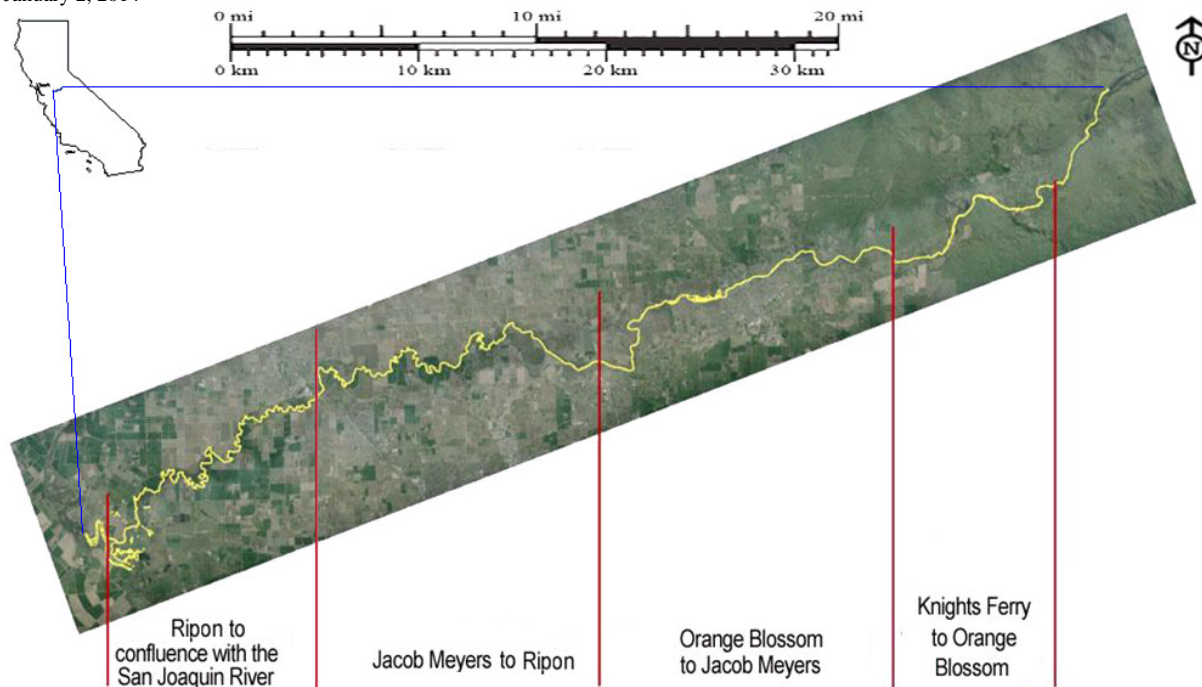


Figure 10
Reaches for Stanislaus River floodplain area versus flow modeling

of the Stanislaus River taken on January 15, 2006 at a flow of 5,000 cfs. Heads up digitizing⁶ was then used to produce a 5,000 cfs water's edge polygon from the georeferenced aerial photos. The polygon was used, with a 10 meter buffer, to produce shapefiles of the portion of the LIDAR and SONAR data that would be used to develop the hydraulic model. A triangular irregular network (TIN) was produced from the LIDAR data to separate the portion of the LIDAR data that was actually ground elevations (steep slopes) from the LIDAR data that was actually water surface elevations (flat slopes). The TIN was used together with NAIP imagery and heads up digitizing to produce a LIDAR water's edge polygon. LIDAR data from within the polygon, consisting of water surface elevations, was then discarded, leaving only ground elevation LIDAR data.

Comma delimited files of the resulting LIDAR and SONAR data were then produced to input into the Surface-water Modeling System (SMS, ver. 10.1.6 64 bit) software, where they were merged to create one scatter data set. A computational mesh was developed in SMS by first defining polygons based on the 5,000 cfs water's edge and LIDAR water's edge polygons. Two material types were defined for the polygons: 1) floodplain for the polygons located between the 5,000 cfs water's edge and LIDAR water's edge polygons; and 2) channel for the polygons located within the LIDAR water's edge polygon. Patch meshes, with rectangular mesh elements

⁶ Heads up digitizing refers to on-screen digitizing, an interactive process in which a map is created using previously digitized or scanned information. In heads up digitizing, the user creates the map layer appearing on the screen with the mouse, with referenced information as a background.

3 meters long (in the longitudinal direction) by 1 or less meters wide (in the lateral direction)⁷, were used for the channel polygons, while 3 meter by 3 meter square paving meshes were used for the floodplain polygons. The scatter dataset was interpolated to the computational mesh using the inverse distance weighted interpolation option in SMS.

We installed pressure transducers near the mouth of the Stanislaus River to use to develop the downstream boundary condition for the hydraulic model of the mouth of Stanislaus River to Ripon reach. The data from these pressure transducers, together with stage and flow data from the Vernalis gage (USGS Gage Number 11303500), located on the San Joaquin River downstream from the mouth of the Stanislaus River, and Stanislaus River flows, were used to develop a regression equation to predict the stage at the mouth of the Stanislaus River from the Vernalis gage rating curve. The stage from the rating table of the Ripon gage (USGS Gage Number 11303000), located at the downstream boundary of the Ripon to Jacob Meyers model, was used as the downstream boundary condition for the hydraulic model of the Ripon to Jacob Meyers reach. The water surface elevation simulated at the upstream end of the Ripon to Jacob Meyers hydraulic model was used as the downstream boundary condition for the hydraulic model of the Jacob Meyers to Orange Blossom reach. We developed a modified rating table for the Orange Blossom gage (California Data Exchange Center Station ID OBB) from historical records of the stage measured at the Orange Blossom gage and the flows at the Goodwin and Ripon gages, to use as the downstream boundary condition for the hydraulic model of the Orange Blossom to Knight's Ferry reach.

The resulting computational mesh was used as an input to SRH-2D (USBR, Denver, CO), along with the above downstream boundary conditions for the hydraulic models of each reach. The hydraulic model was calibrated by running the model at 1,500 cfs for the upper three reaches and 1,320 cfs for the lower reach (the flow at which we had measured the WSEL at the downstream boundary location), and varying the Manning's n values for the channel and floodplain, with the resulting simulated water surface elevations compared to those from measurements or gage rating curve values at the following locations: 1) the Ripon gage for the mouth of Stanislaus River to Ripon reach; 2) the McHenry instream flow study site, located approximately half-way through the Ripon to Jacob Meyers reach; 3) the Orange Blossom gage and the Valley Oak site, located approximately half-way through the Jacob Meyers to Orange Blossom reach; and 4) the Horseshoe site, located approximately half-way through the Orange Blossom to Knight's Ferry reach. We used initial Manning's n values of 0.025 for the channel and 0.07 for the floodplain, based on values used by cbec Engineering for the Orange Blossom Bridge to Knight's Ferry reach (Chris Hammersmark, cbec Engineering, personal communication).

The calibrated model was then used for hydraulic simulations at flows ranging from 250 to 5,000 cfs, with the above downstream boundary conditions. The model output was then processed in SMS to compute the total wetted area at each flow. The resulting total wetted area versus flow graph was then examined to determine the flow at which floodplain inundation begins, as shown

⁷ Mesh elements one meter wide were used for wider portions of the channel while narrower elements were used for narrower portions of the channel.

by an inflection point in the graph. The total wetted area at higher flows was then subtracted from the total wetted area at which floodplain inundation begins to determine the inundated floodplain area at each flow.

Results

The equation for the downstream boundary condition for the mouth of the Stanislaus River to Ripon reach is: Boundary condition = Vernalis gage height + 5.75 + 0.000329 x Stanislaus flow – 0.000273 x Vernalis flow ($R^2 = 0.88$). The Vernalis flow used in the above equation is the sum of the Stanislaus River simulation flow and 1,608 cfs, the median flow for the San Joaquin River above the Stanislaus River for the period of record of the Ripon and Vernalis gages (October 1, 1940 through April 4, 2012). The flow of the San Joaquin River above the Stanislaus River was calculated as the difference between the flows at the Vernalis and Ripon gages. Calibration of the mouth of the Stanislaus River to Ripon reach indicated that the best Manning's n values were 0.0235 for the channel and 0.07 for the floodplain. With these Manning's n values and the water surface elevation that we measured at the mouth of the Stanislaus River on April 6, 2012, the water surface elevation predicted at the Ripon gage was 0.01 feet lower than the rating table value at 1,320 cfs.

In FY 2013, we completed hydraulic simulations for the Jacob Meyers to Orange Blossom reach, and conducted the calibration and hydraulic simulations for the mouth of the Stanislaus River to Ripon reach. We will not be able to develop hydraulic models for the Goodwin Dam to Knight's Ferry Bridge reach, since SONAR data is not available for that reach. The Jacob Meyers to Orange Blossom reach shows floodplain inundation starting at 1,000 cfs, while the mouth of the Stanislaus River to Ripon reach shows floodplain inundation starting at 1,500 cfs (Figures 11 and 12). Figure 13 shows the combined floodplain inundation area versus flow relationship for the four reaches.

Discussion

The relationship between flow and inundated floodplain area, together with historical stream gage data, can be used to compute the number of acre-days of inundated floodplain for an appropriate period of each year, such as February 1 to June 15. This metric can be used in a regression analysis with juvenile survival estimates based on rotary screw trap data to understand how inundated floodplain area affects juvenile survival. The relationship can also be used in developing instream flow recommendations for outmigrant anadromous salmonids, and the modeling can be used to prioritize areas for restoring/creating floodplain habitat.

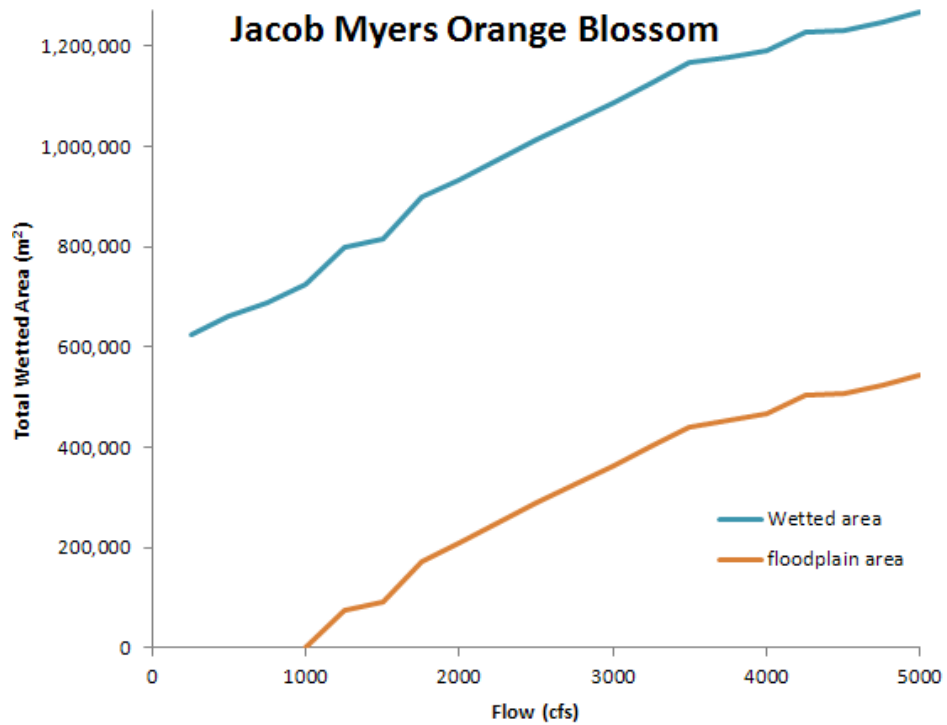


Figure 11

Floodplain versus flow relationship for the Jacob Meyers to Orange Blossom reach

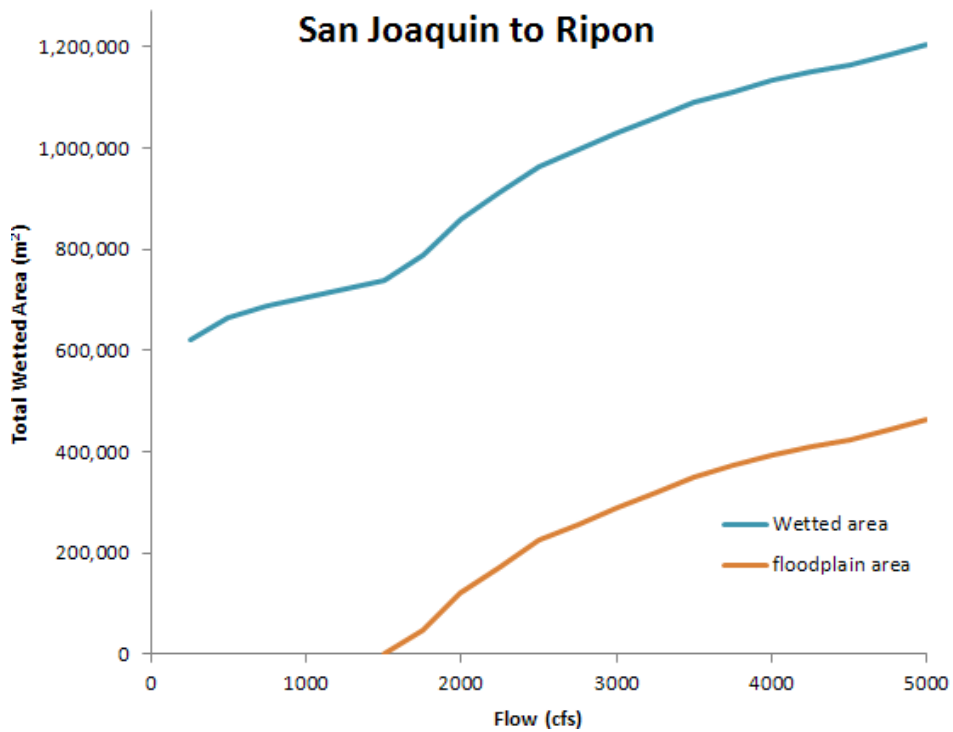


Figure 12

Floodplain versus flow relationship for the mouth of the Stanislaus River to Ripon reach

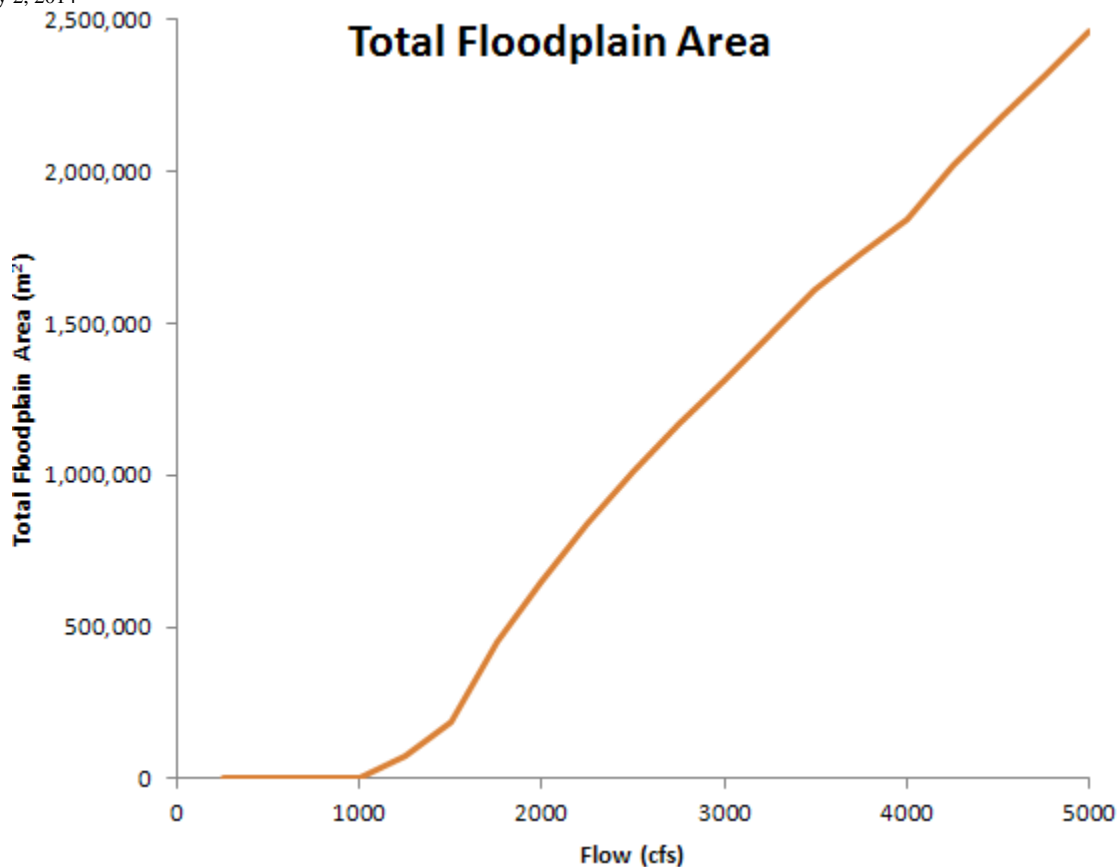


Figure 13

Floodplain versus flow relationship for the entire modeled portion of the Stanislaus River

Stanislaus River Floodplain Restoration Project Monitoring

Methods

This task involved work on the Button Bush project, where the tasks were ground-truthing LIDAR data and collecting deep-water topography data, with the ultimate goal of producing an integrated topographic dataset that can be used to design a floodplain restoration project at Button Bush. For the Button Bush site, there was a previous source of topographic data, a portion of the LIDAR and SONAR data discussed above for the Stanislaus River floodplain versus flow relationship task. The LIDAR data had a nominal vertical accuracy of ± 0.5 feet. We systematically selected 300 LIDAR points within the Button Bush site and navigated to them with the survey grade RTK GPS; we used the stake-out feature of the RTK GPS to determine the difference between the given elevation of the LIDAR points and the elevation measured with the RTK GPS. Due to time constraints, equipment problems and heavy brush, we were only able to navigate to 194 of these points. We used the methods described above for the American River gravel project to collect bed topography in the wetted channel using our ADCP and survey grade RTK GPS. This data will be used to supplement the SONAR data and to determine if there have been changes in the channel topography since the SONAR data was collected in 2008. We also

established a horizontal and vertical control on the project site, consisting of a t-post, protruding four inches from the ground, on the left bank (looking upstream), 50 feet from the water's edge and located a little more than half-way up the site.

Results

For the Button Bush project, we were able to stake out 89 of the LIDAR points; of the remaining 105 points that we were able to navigate to, 101 could not be staked out because the RTK GPS stayed in float due to being under vegetation, two points ended up being on the other side of the fenceline (on private property), and we were not able to get to two points due to heavy brush in the way⁸. Of the 89 points we staked out, 63 (70.7%) had elevations within 0.5 feet of the LIDAR elevations. For two of the 89 points, the LIDAR elevation was actually the water surface elevation of an off-channel area. For the points where the difference was more than 0.5 feet, no points had groundtruthed elevations that were more than 0.5 feet higher than the LIDAR elevations, while 26 points had groundtruthed elevations that were more than 0.5 lower than the LIDAR elevations. The average difference in elevation between the LIDAR and ground-truthing elevations for the 89 points, excluding the two points where the LIDAR elevation was the water surface elevation, was 0.089 m. We collected 3,681 topographic data points in the wetted channel. The coordinates of the control, in Universal Transverse Mercator (UTM) Zone 10, NAD83 meters, NAVD88, are (4,184,613.458, 698,757.316, 40.558).

Discussion

The LIDAR data is sufficiently accurate for purposes of designing the Button Bush restoration project, although less excavation than planned will likely be needed in highly vegetated areas during construction. It is likely that the elevations of the LIDAR data in highly vegetated areas are too high because the last return was off of vegetation instead of the ground. The combined dataset of topographic data from LIDAR, ADCP and SONAR should serve as a good topographic dataset for designing the Button Bush restoration project.

Tuolumne River Bobcat Flat Pre and Post-restoration Monitoring

Methods

We established a 1,280 foot long pre-restoration study site that included all of the mesohabitat types (Bar Complex Run, Bar Complex Riffle, Bar Complex Pool and Flatwater Run) present in the restoration site. This study site has one downstream boundary and two upstream boundaries – one with the main river flow, and the other where a side channel enters the river. As a result, an additional data item was needed – the discharge of the side channel at three flows, to develop a flow-flow regression between the side channel and total Tuolumne River flow. We used the same methods given above for the American River to collect the remaining data needed to develop a pre-restoration hydraulic and habitat model of the Bobcat Flat site. We also collected

⁸ The RTK GPS would likely have stayed in float at these points as well.

additional data upstream of the study site, using the same methods, to supplement existing LIDAR and SONAR data, for purposes of developing an upstream extension for the hydraulic model.

The post-restoration study site coincided with the pre-restoration study site, except that the post-restoration study site extended further downstream on one bank, so that the downstream boundary of the post-restoration study site was perpendicular to the flow in the restored habitat. The data for the post-restoration study site was collected using the same methods as for the pre-restoration study site. Bed and mesh files for the pre and post-restoration study sites were developed using the same methods given above for the American River.

Results

We completed all pre and post-restoration data collection. We used a different technique in PHABSIM (MANSQ) to develop the stage-discharge relationships for the upstream and downstream boundary conditions for the pre-restoration study site, since we only have two sets of WSEL measurements to use in developing these stage-discharge relationships. We completed hydraulic and habitat modeling to quantify the amount of spawning and rearing habitat created by the Bobcat Flat project (Figures 14 to 19). Habitat modeling used habitat suitability criteria developed for the Yuba River.

Discussion

The habitat effects of the Bobcat Flat restoration project varied with flow, life stage and species, reflecting differing habitat requirements and changes in hydraulic conditions with flow. The Bobcat Flat restoration project had the biggest benefit for fall-run Chinook salmon spawning, reflecting the in-channel focus of the project on adding spawning gravel. The decrease in the amount of fall-run Chinook salmon fry rearing habitat at almost all flows was likely due to the removal of riparian vegetation during construction, and thus will likely be a short-term impact. We would expect the amount of fall-run Chinook salmon fry rearing habitat to return to pre-restoration levels once riparian vegetation has regrown. Similarly, the amount of fall-run Chinook salmon juvenile rearing habitat should increase with time as riparian vegetation regrows, and thus there will likely be a long-term increase in fall-run Chinook salmon juvenile rearing habitat at all flows. The effects of the Bobcat Flat restoration project on steelhead spawning habitat will depend on the flow regime present during steelhead spawning, given the slight decrease in steelhead spawning habitat at lower flows, but substantial increase in steelhead spawning habitat at higher flows. The Bobcat Flat restoration project will likely have a positive effect on steelhead fry and juvenile rearing habitat, given that Tuolumne River flows are typically lower than 2000 cfs. It should be noted that this assessment does not include the effects of the Bobcat Flat restoration project on floodplain habitat. Our analysis was largely restricted to in-channel habitat due to time constraints in data collection.

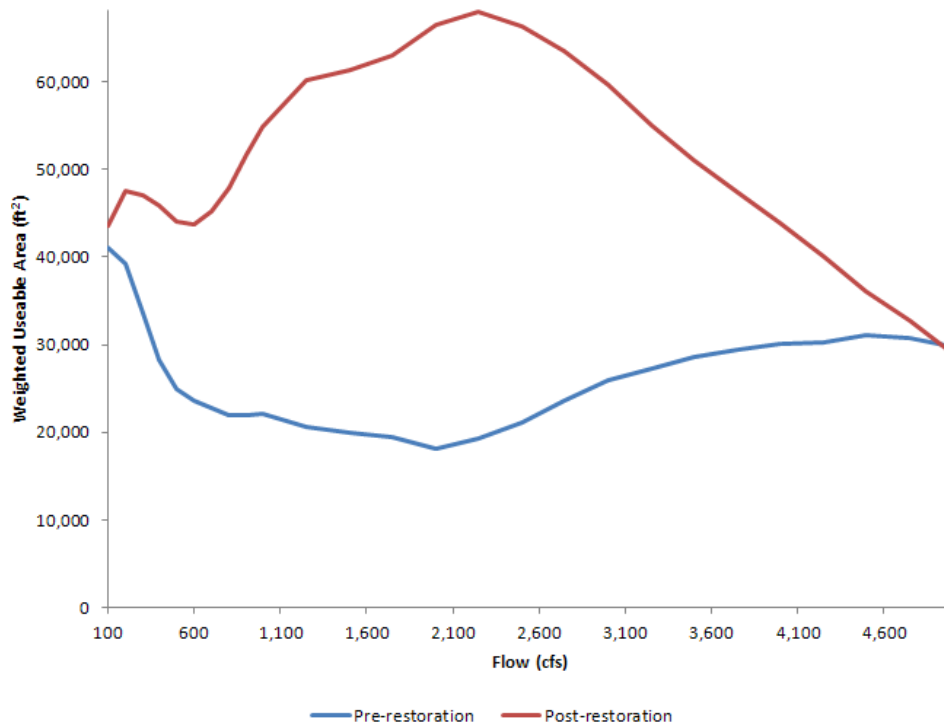


Figure 14

Bobcat Flat fall-run Chinook salmon spawning flow-habitat relationships

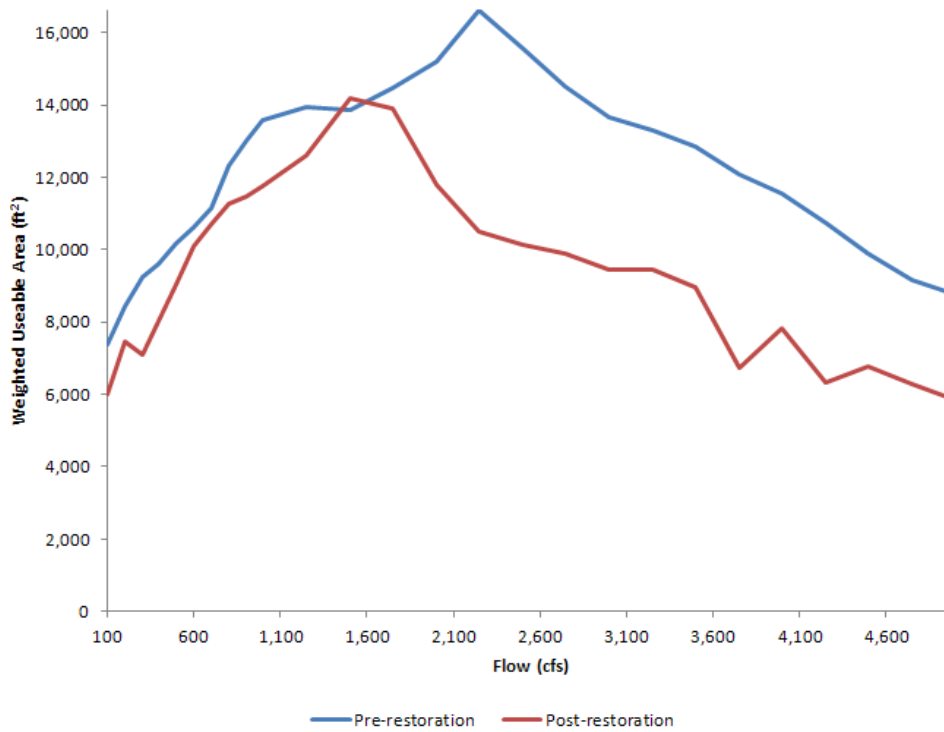


Figure 15

Bobcat Flat fall-run Chinook salmon fry rearing flow-habitat relationships

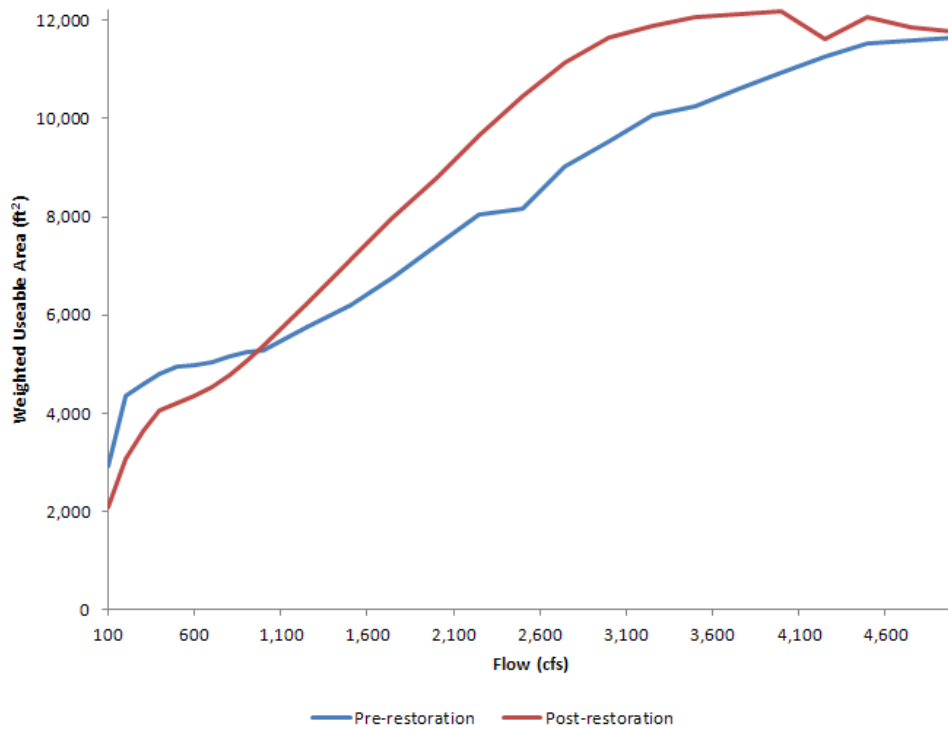


Figure 16

Bobcat Flat fall-run Chinook salmon juvenile rearing flow-habitat relationships

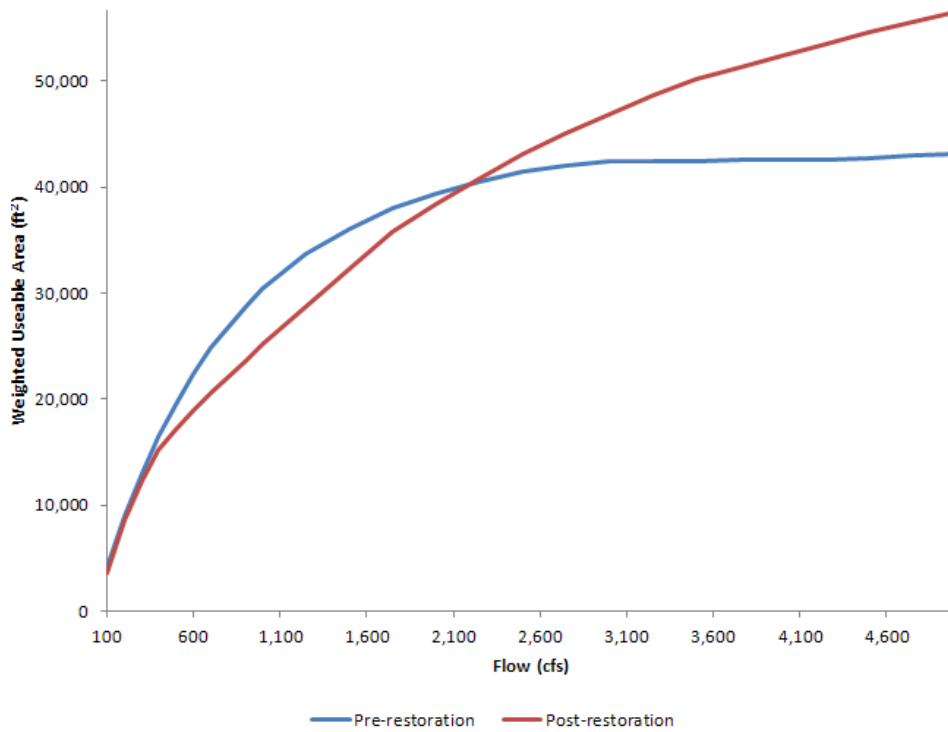


Figure 17

Bobcat Flat steelhead spawning flow-habitat relationships

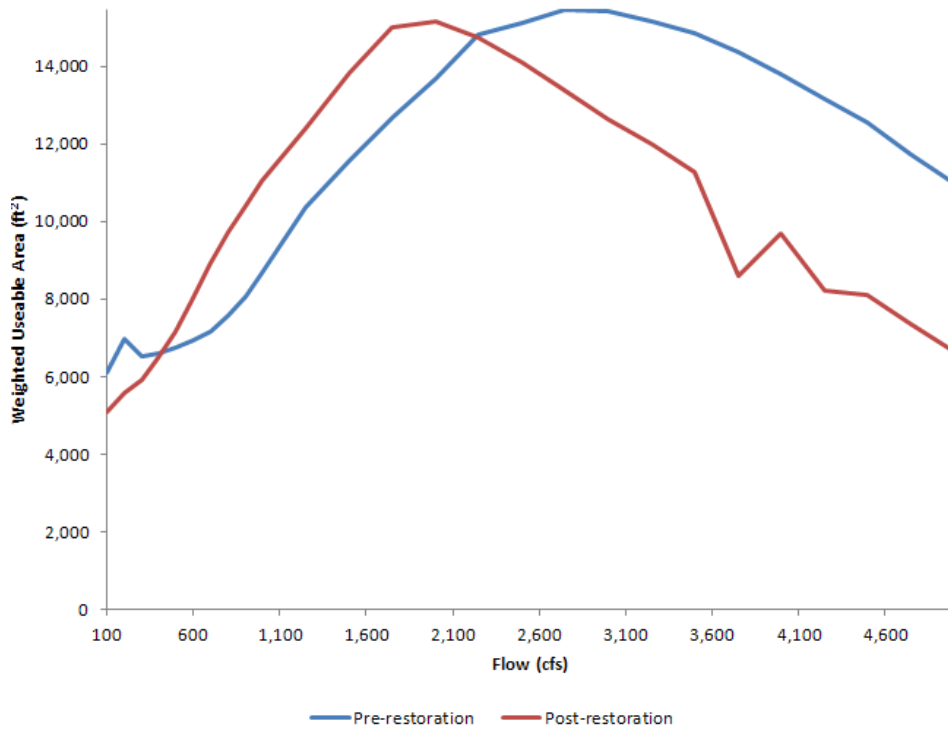


Figure 18
Bobcat Flat steelhead fry rearing flow-habitat relationships

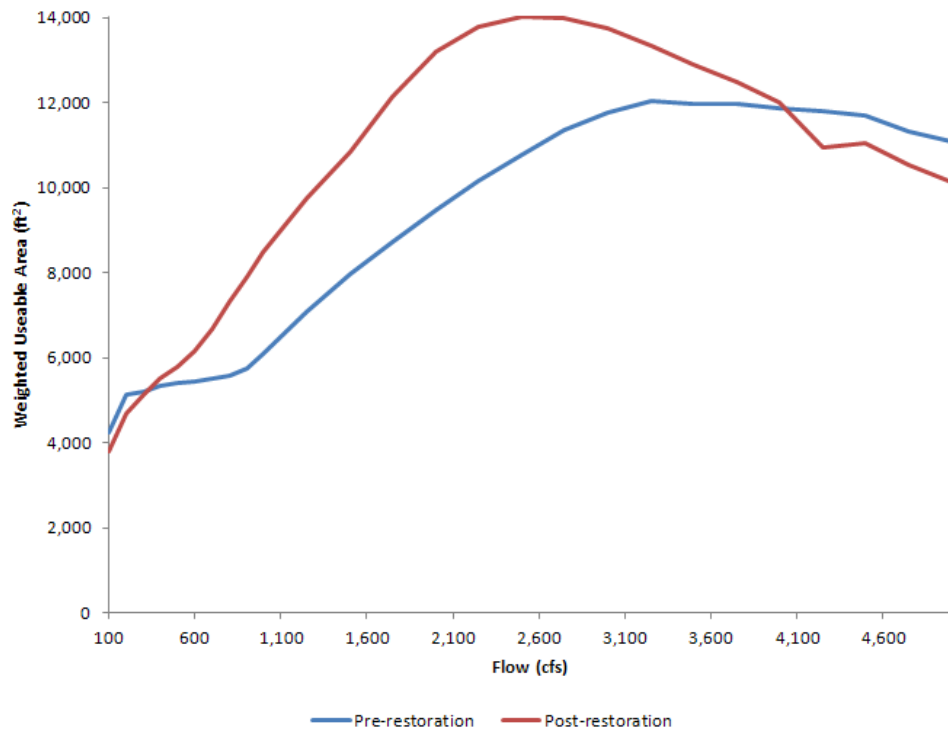


Figure 19
Bobcat Flat steelhead juvenile rearing flow-habitat relationships

Sacramento River Green Sturgeon Spawning HSC Data Collection

Methods

The Red Bluff Fish and Wildlife Office placed egg mats to sample for green sturgeon spawning on the Sacramento River at 11 sites from April 25, 2008 to July 14, 2012. Flows during the sampling ranged from 5,030 to 20,200 cfs. The Red Bluff Fish and Wildlife Office measured depths but did not measure velocities or substrate sizes at the egg mat locations. A total of 90 mats at seven of the sites ended up catching green sturgeon eggs. For one of the sites, just downstream of Red Bluff Diversion Dam, the hydraulic conditions had changed since the sampling due to the Red Bluff Diversion Dam gates being permanently raised. We were provided with geographic coordinates where the egg mats at the remaining six sites (GCID, Red Barn, Antelope, Turkey Beach, Massacre Flat and Inks Creek) were placed. On May 28-31, 2013, we navigated to the subset of these locations where eggs were found (a total of 86 mats) using our survey-grade RTK GPS and measured depth and velocity at the locations using our ADCP. We also visually classified the substrate at each location where we measured depths and velocities, using the substrate codes in Table 1 and underwater video equipment (Gard and Ballard (2003)). We also mapped out bed elevations, depths and velocities throughout the areas sampled with the egg mats, using the same methods given above for the deeper areas of the American River gravel sites, and collected data for one PHABSIM transect at each of the six sites to use to simulate the velocities that were present during the egg mat sampling. Flows during our data collection ranged from 12,069 to 12,400 cfs.

Results

The bed topography of the six study sites are shown in Figures 20 to 25. We were able to measure depths, velocities and substrate sizes at the mats with eggs. We used the mapping of depths and velocities throughout the areas sampled with the egg mats (Figures 26 to 37) to interpolate the depths and velocities at mat locations without eggs. The measured or interpolated depth, together with the depth measured during the egg mat sampling, the measured or interpolated velocity, and the PHABSIM transects, were used to simulate the velocities that were present during the egg mat sampling. Depths and velocities that were present during the egg mat sampling for the 86 mats where green sturgeon eggs were collected (occupied locations) ranged from 7.8 to 36.9 feet and 0.81 to 5.64 feet/sec (Figures 38 and 39), while substrate sizes ranged from fines to 4-6", plus bedrock (Figure 40). Depth and velocities that were present during the egg mat sampling for unoccupied mats (where green sturgeon eggs were not collected) ranged from 1.7 to 47.5 feet and 0.17 to 6.93 feet/sec.

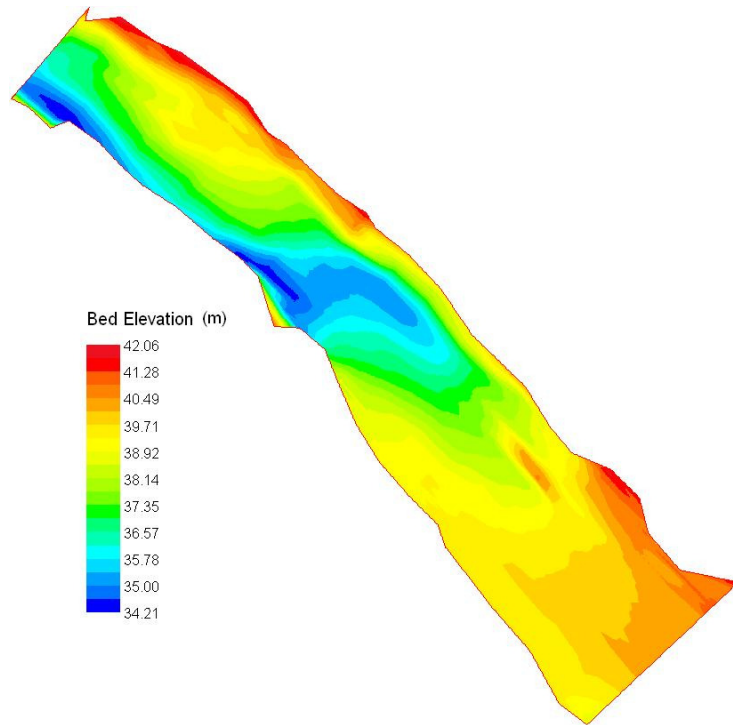


Figure 20
Sacramento River Topography at GCID

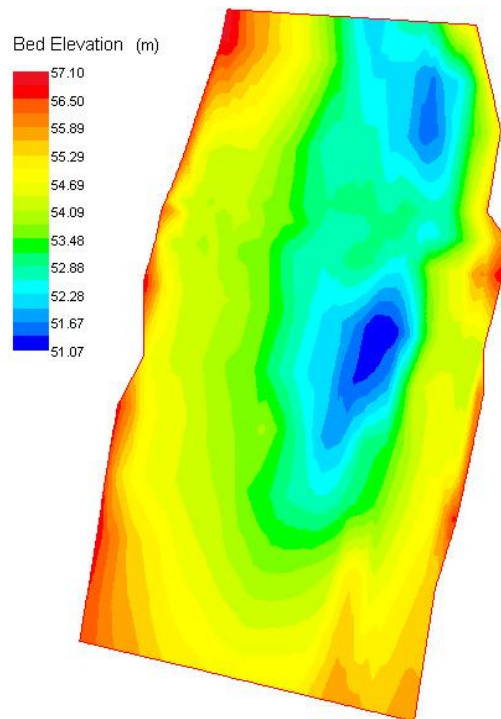


Figure 21
Sacramento River Topography at Red Barn

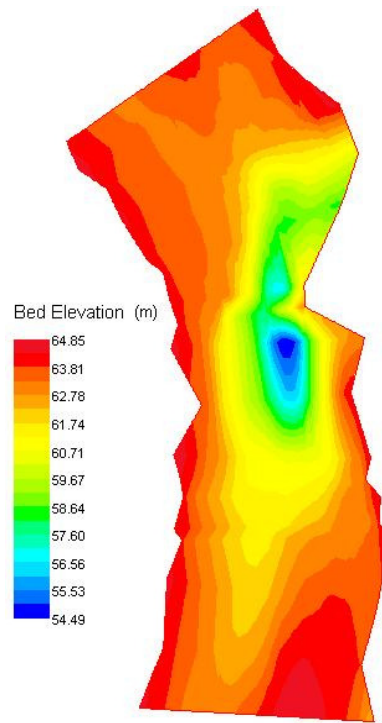


Figure 22
Sacramento River Topography at Antelope

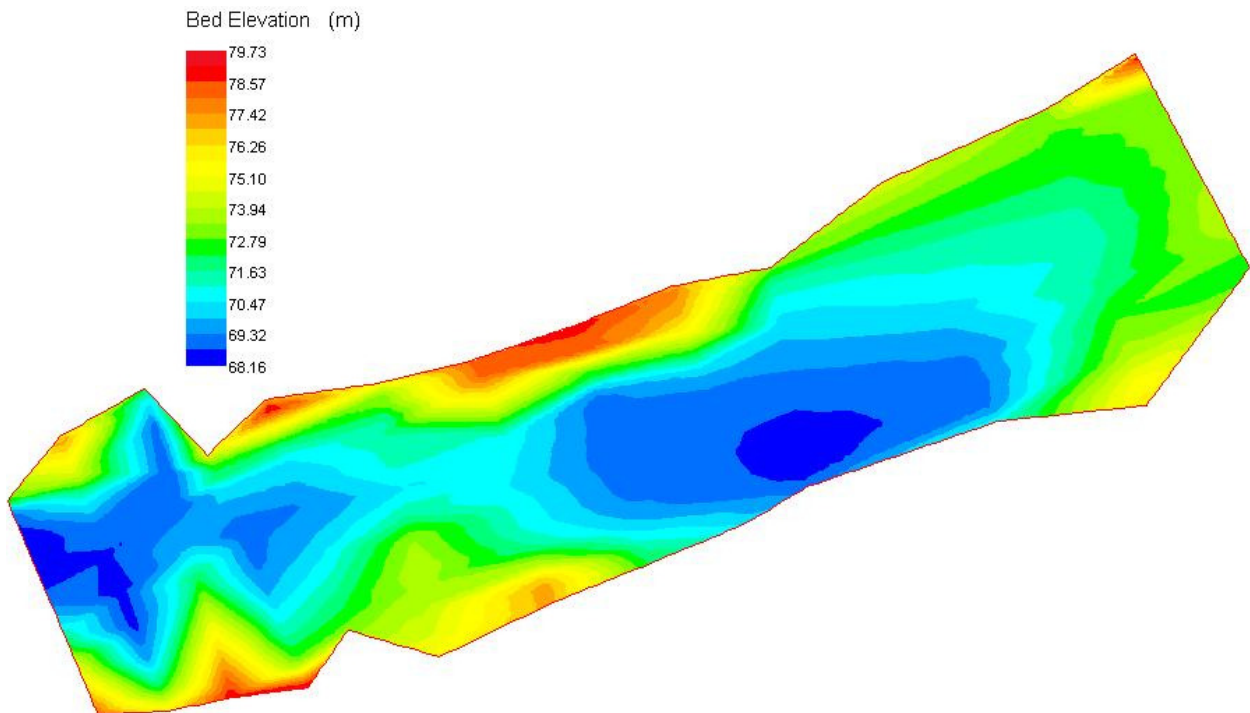


Figure 23
Sacramento River Topography at Turkey Beach

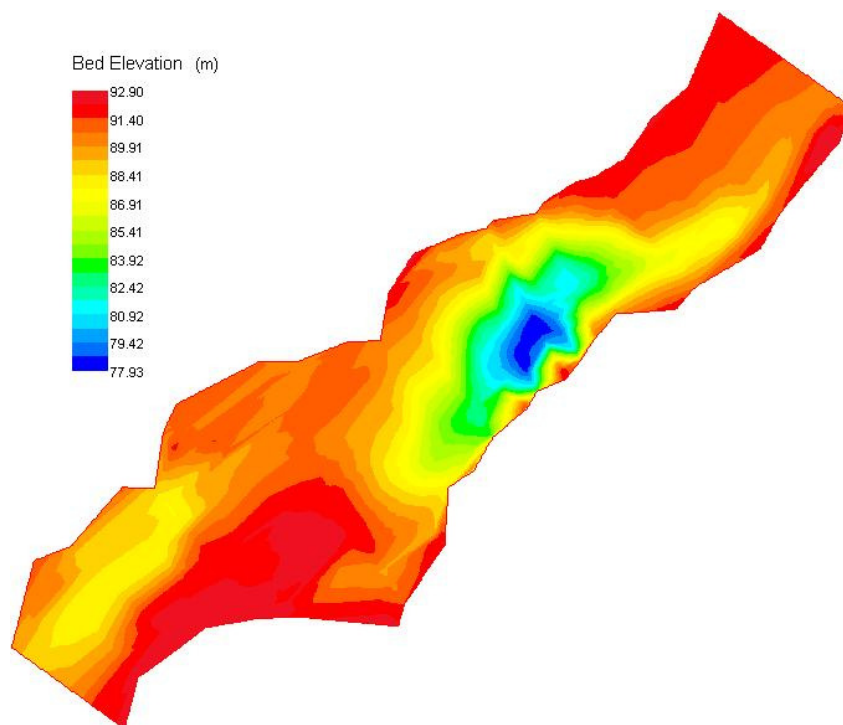


Figure 24
Sacramento River Topography at Massacre Flat

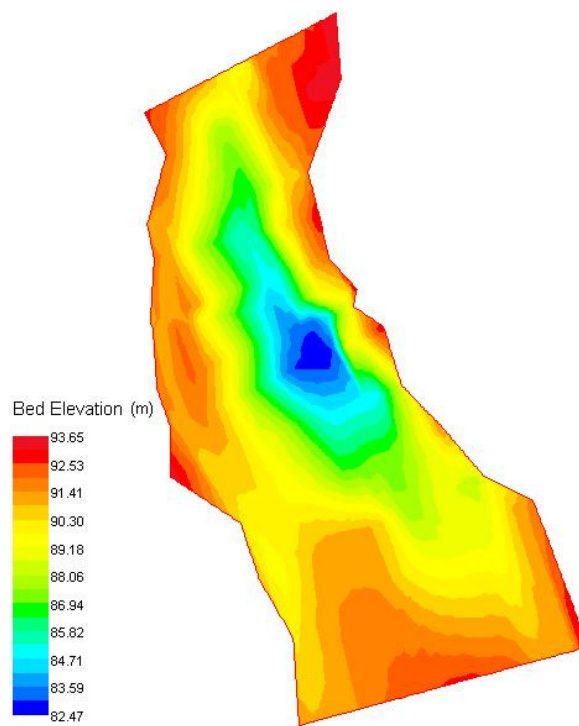


Figure 25
Sacramento River Topography at Inks Creek

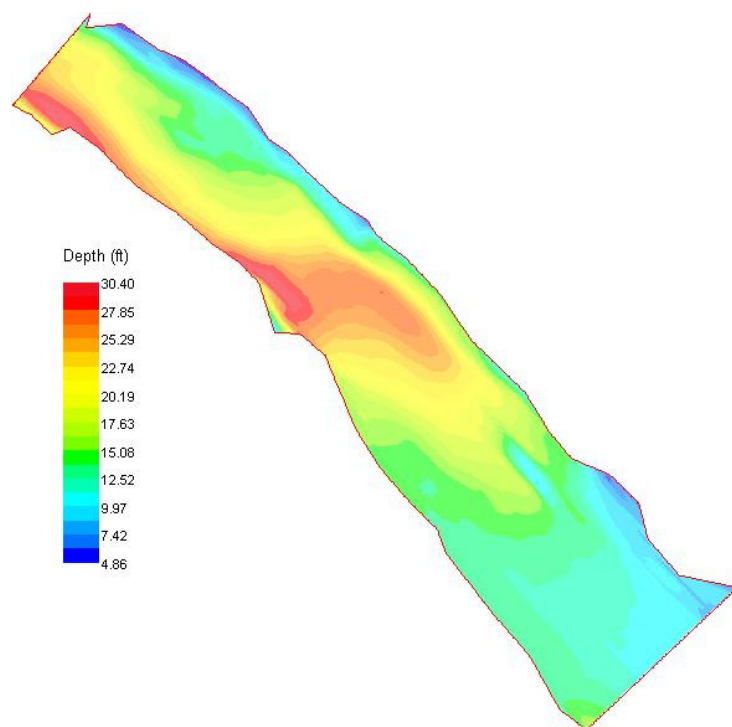


Figure 26
Sacramento River Depths at GCID on May 28, 2013

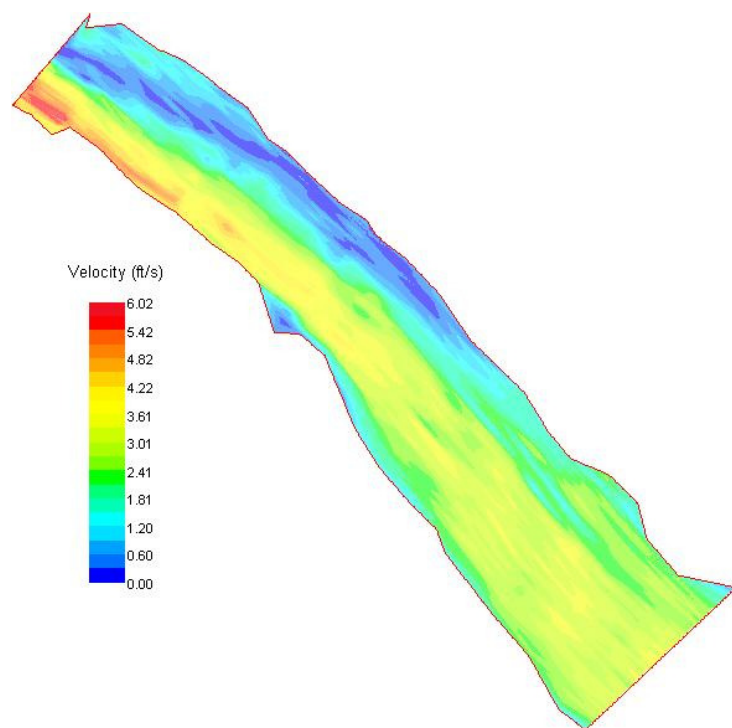


Figure 27
Sacramento River Velocities at GCID on May 28, 2013

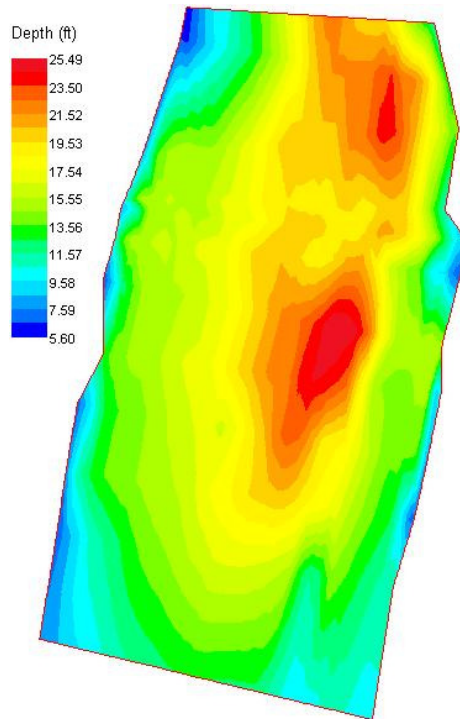


Figure 28
Sacramento River Depths at Red Barn on May 29, 2013

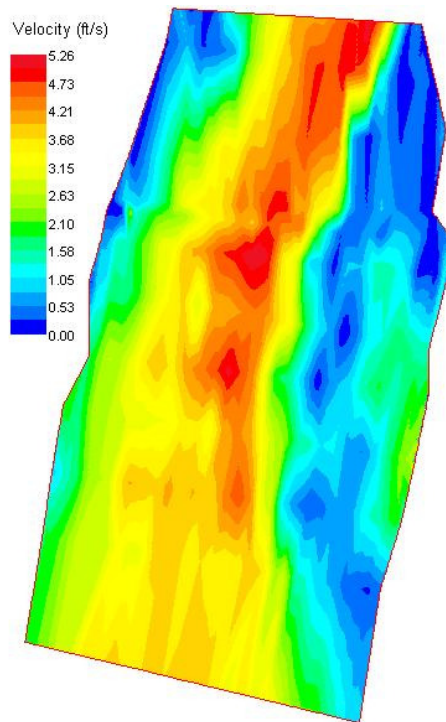


Figure 29
Sacramento River Velocities at Red Barn on May 29, 2013

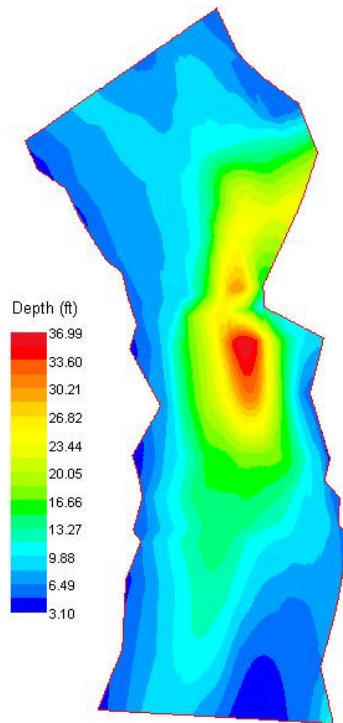


Figure 30
Sacramento River Depths at Antelope on May 29, 2013

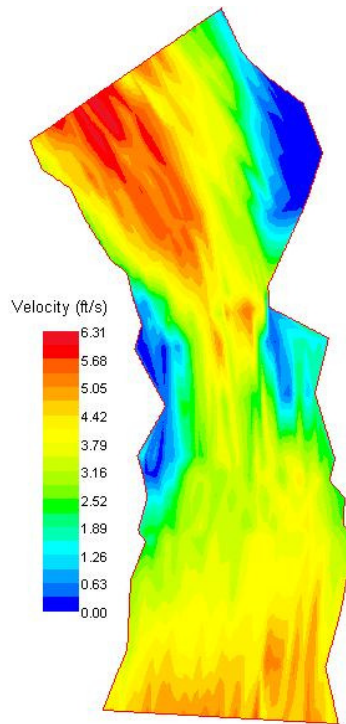


Figure 31
Sacramento River Velocities at Antelope on May 29, 2013

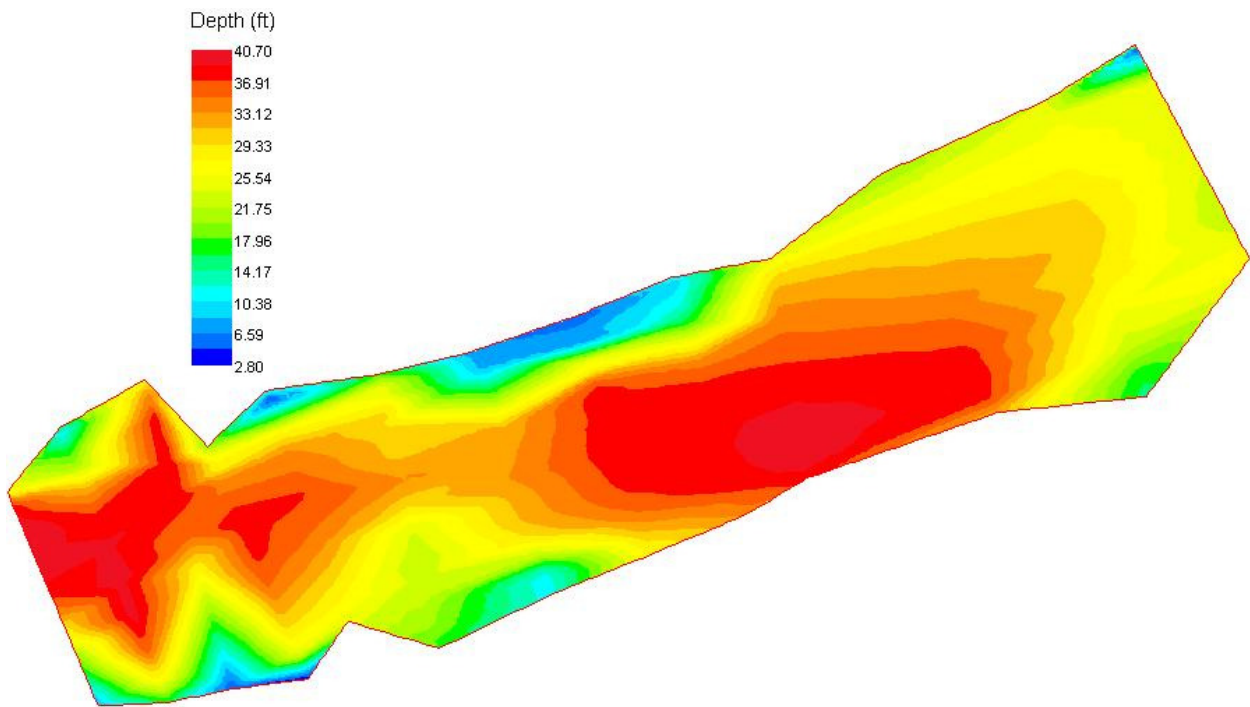


Figure 32
Sacramento River Depths at Turkey Beach on May 31, 2013

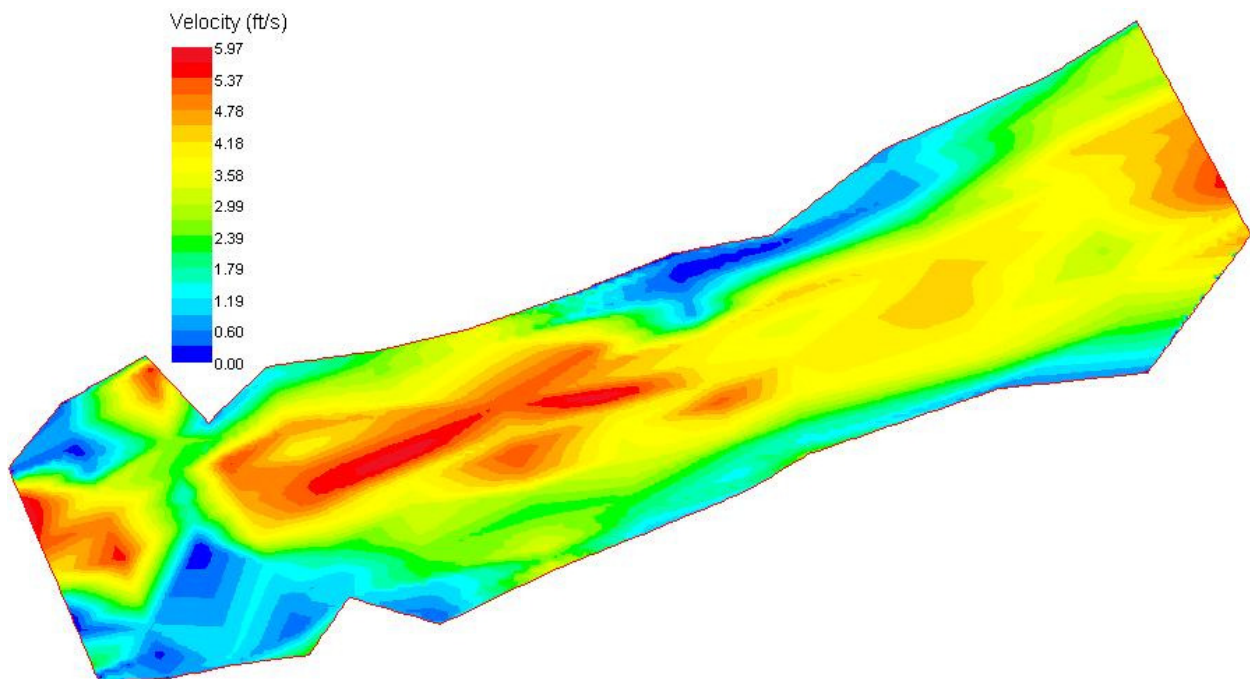


Figure 33
Sacramento River Velocities at Turkey Beach on May 31, 2013

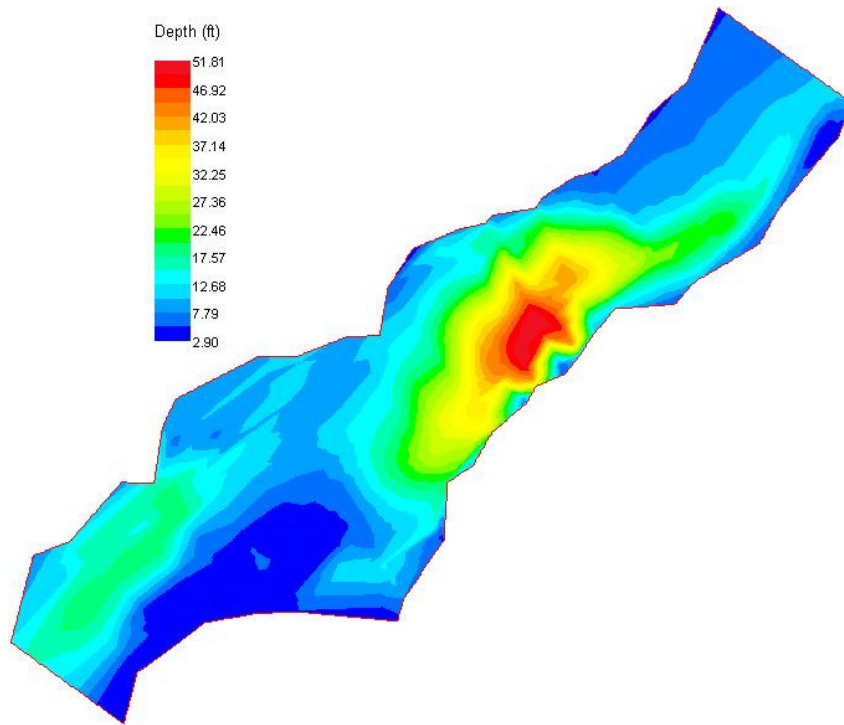


Figure 34
Sacramento River Depths at Massacre Flat on May 30, 2013

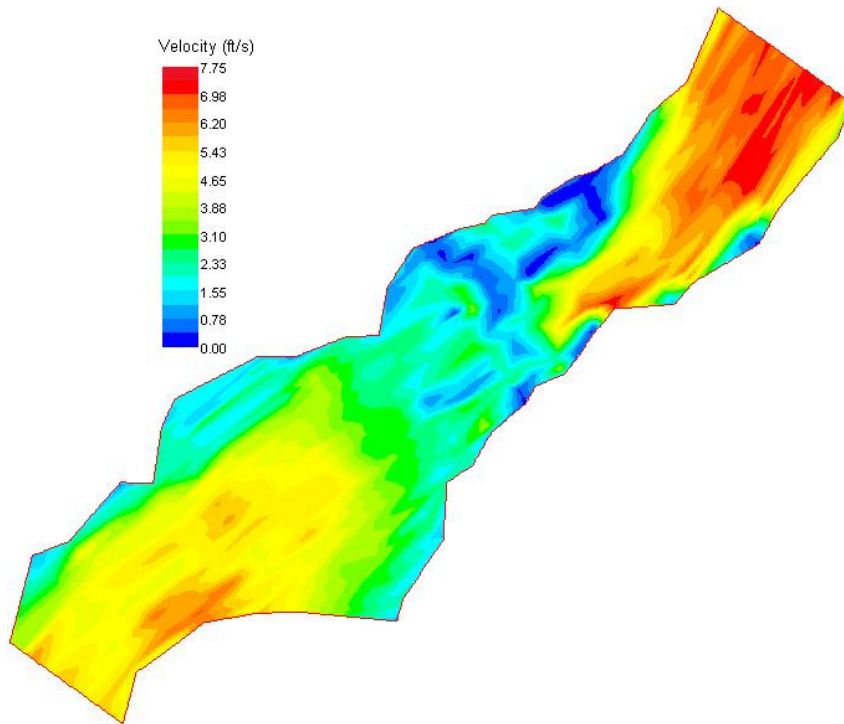


Figure 35
Sacramento River Velocities at Massacre Flat on May 30, 2013

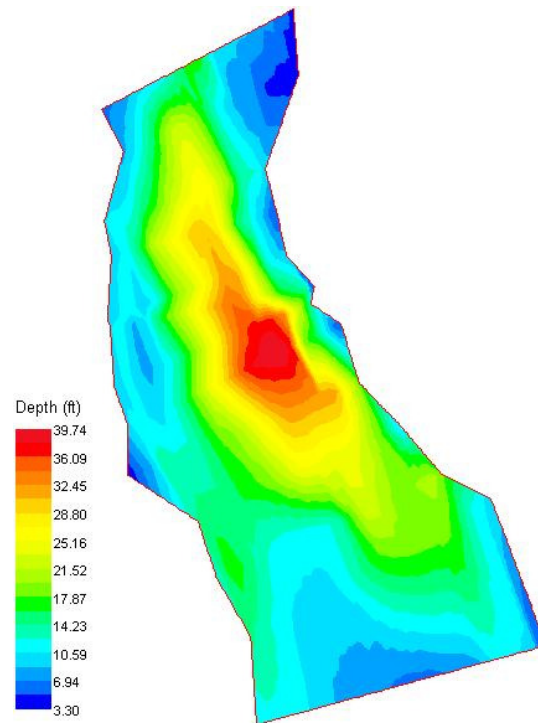


Figure 36
Sacramento River Depths at Inks Creek on May 30, 2013

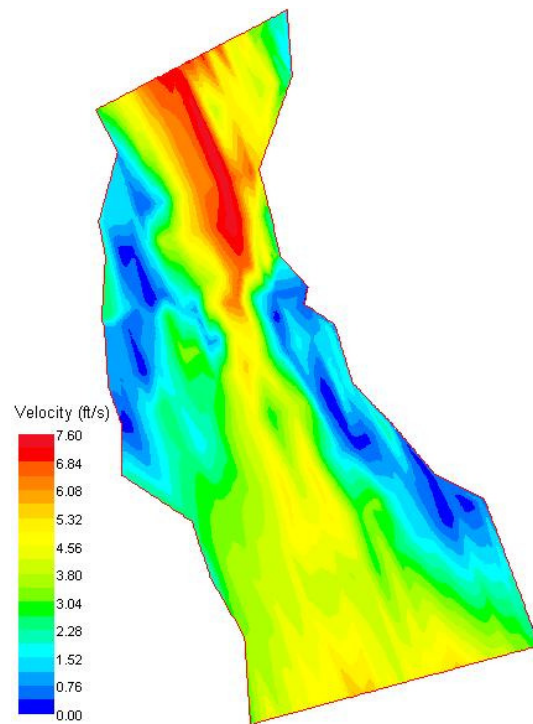


Figure 37
Sacramento River Velocities at Inks Creek on May 30, 2013

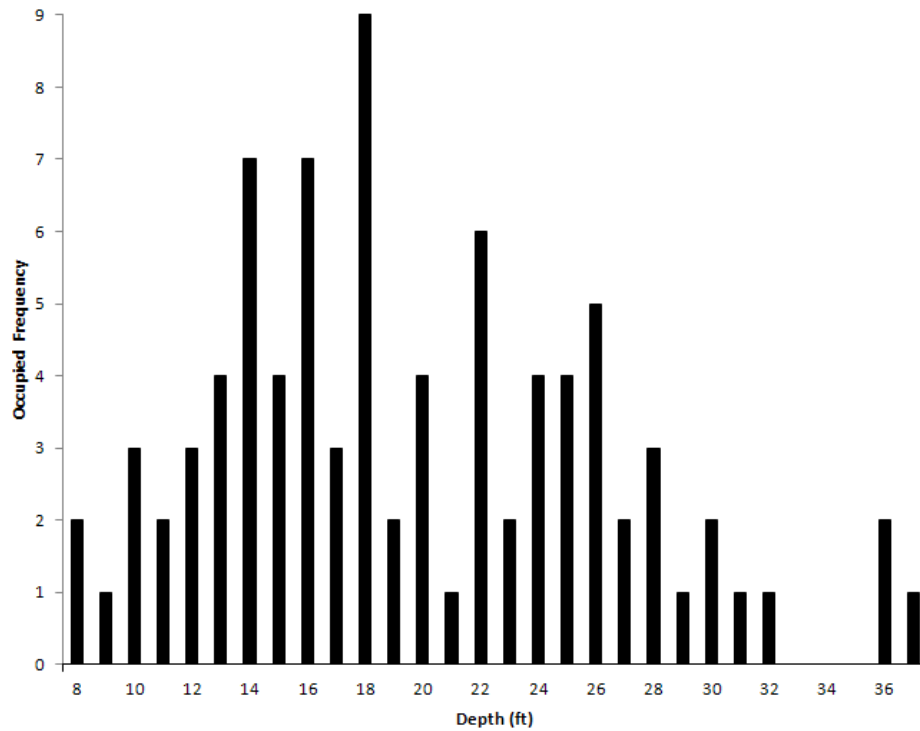


Figure 38

Sacramento River Depths at Mats with Green Sturgeon Eggs

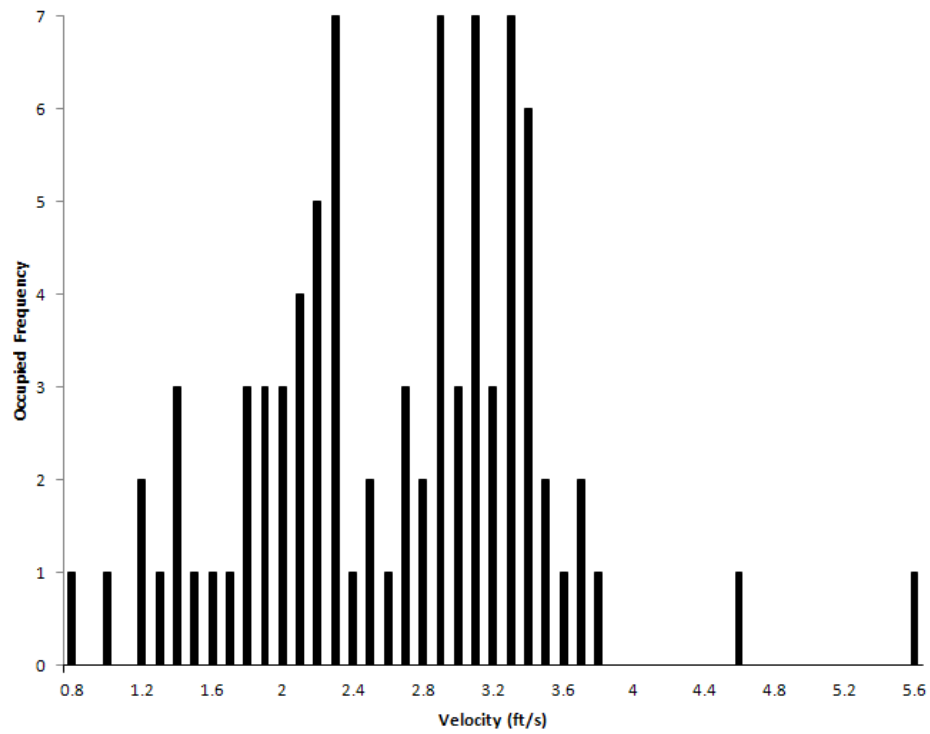


Figure 39

Sacramento River Velocities at Mats with Green Sturgeon Eggs

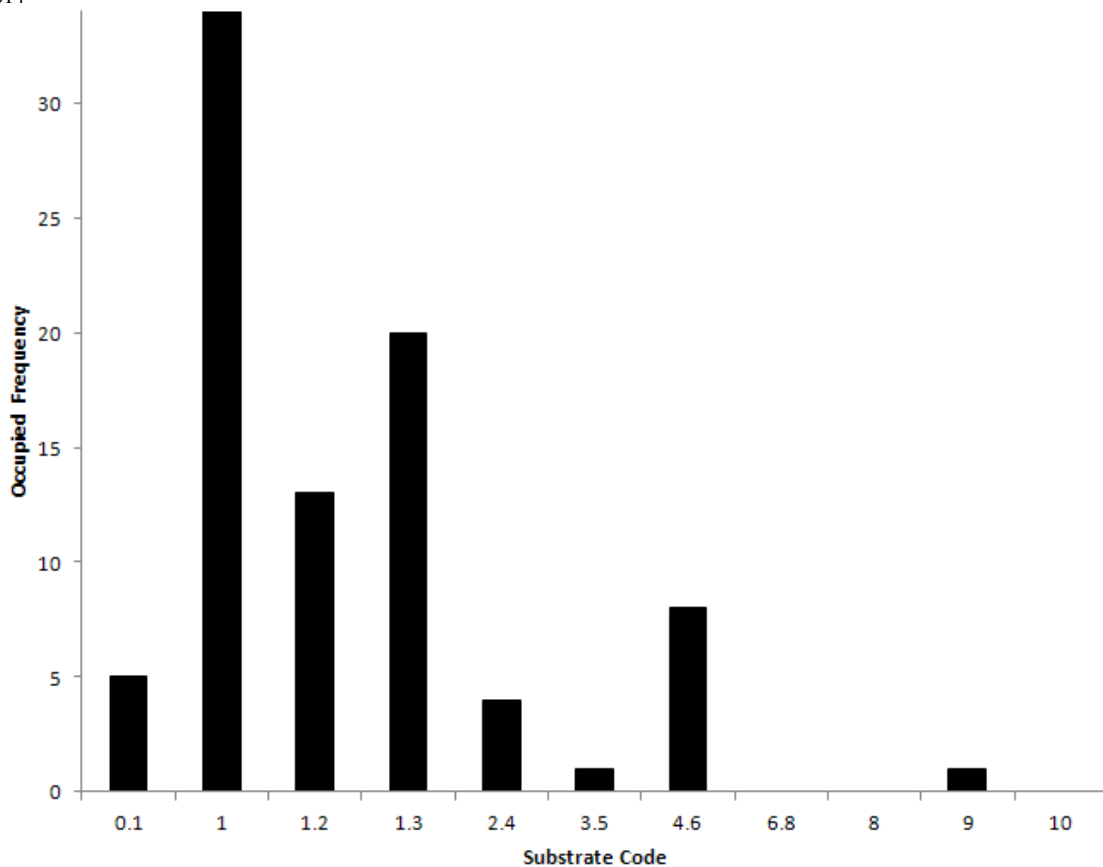


Figure 40
Sacramento River Substrate Codes at Mats with Green Sturgeon Eggs

Discussion

This data, in itself, is too small a sample size to develop spawning habitat suitability criteria for green sturgeon⁹. The depths and velocities at the occupied locations fell within the range of depths and velocities at the unoccupied locations, suggesting that green sturgeon were able to select their preferred habitat conditions. We suggest that this data be combined with data from other locations in the Central Valley to develop green sturgeon spawning criteria with a Delphi process, as we did for Sacramento River white sturgeon (U.S. Fish and Wildlife Service 1996).

Clear Creek inSALMO Model Beta Testing

Methods

In 2011, Lang, Railsback and Associates and USDA Forest Service, Pacific Southwest Research Station, developed the Improvement of Salmon Life-Cycle Framework Model (inSALMO) individual-based Chinook salmon model (Railsback et al. 2012) and applied it to two sites on

⁹ There needs to be a minimum of 150 observations for each life stage and species (Bovee 1986).

Clear Creek (3A and 3C), using as input hydraulic modeling that we had conducted for these sites. In 2012, the model was extended to more of our sites on Clear Creek, while in 2013 the model was extended to all of our sites on Clear Creek. We performed simulation runs for these sites at 2,000, 5,000, 10,000 and 50,000 cfs, so that the inSALMO model could be applied for the entire range of historic flows on Clear Creek.

Results

We completed high flow simulation runs for the remaining sites in FY 2013. This effort is now complete. Additional information on the inSALMO model can be obtained from Steve Railsback (Steve@langrailsback.com) and at: http://www.fws.gov/sacramento/fisheries/Instream-Flow/fisheries_instream-flow_inSalmo.htm.

Yuba River Hammon Bar Restoration Project Monitoring

Methods

In FY 2012, we collected topographic, substrate and cover data at the Hammon Bar pilot riparian restoration site on the Yuba River, using the methods described above for the American River. In FY 2013, we combined this data with additional topography data from Greg Pasternack, covering the areas we were unable to sample due to time constraints (primarily a downstream extension). The combined dataset was used to develop pre-, post-restoration and grow-out bed and mesh files, using the methods given above for the American River. Grow-out conditions were simulated by assuming that the cover code for all of the planting locations would eventually either be 3.7 or 4.7, depending on the cover code present during data collection. The computation mesh was used in River2D, along with water surface elevations from Greg Pasternack's entire Yuba River hydraulic model (as the downstream boundary condition) to model fry and juvenile Chinook salmon and steelhead/rainbow trout habitat for flows ranging from 2,000 to 42,200 cfs¹⁰, using the habitat suitability criteria from our Yuba River instream flow study, for pre-, post-restoration and grow-out conditions. In FY 2014, we will be repeating this data collection and modeling for the second year of plantings at the Hammon Bar riparian restoration site.

Results

Results are shown in Figures 41 to 44.

¹⁰ A flow of 2,000 cfs is the flow at which the restoration site begins to be inundated, while 42,200 cfs is the highest flow simulated by Greg Pasternack's model.

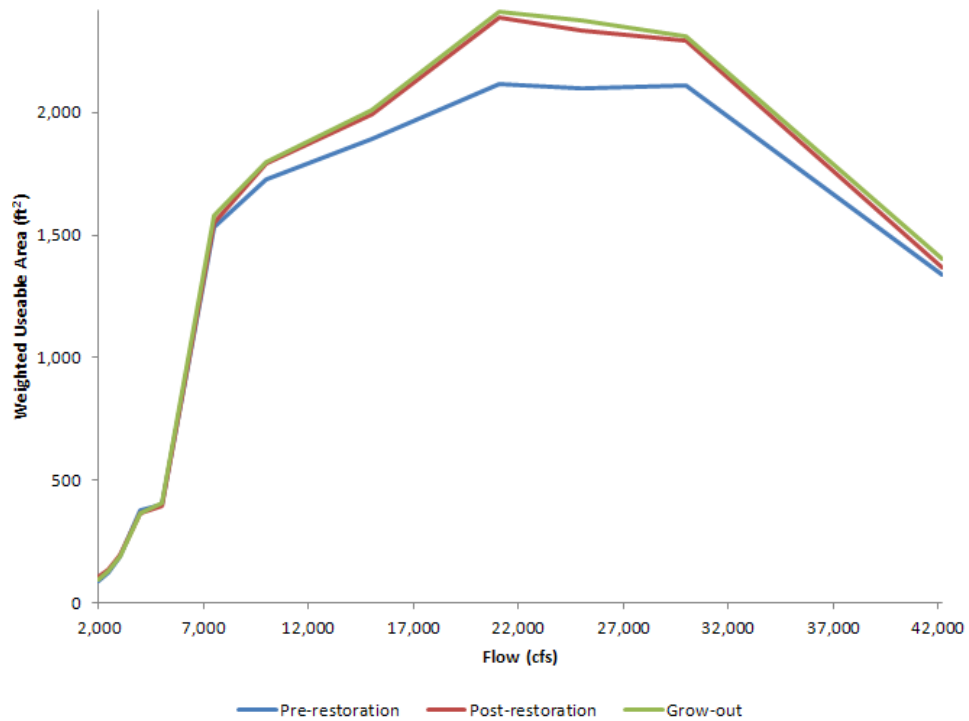


Figure 41

Hammon Bar fall-run Chinook salmon fry rearing flow-habitat relationships before, after and at grow-out of the pilot riparian plantings

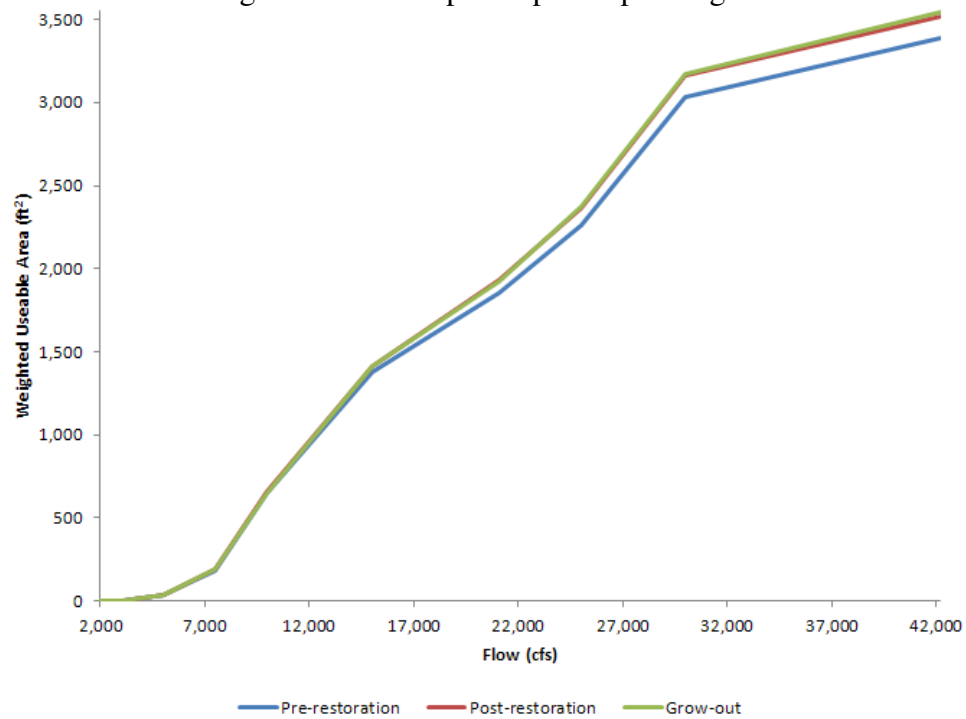


Figure 42

Hammon Bar fall-run Chinook salmon juvenile rearing flow-habitat relationships before, after and at grow-out of the pilot riparian plantings

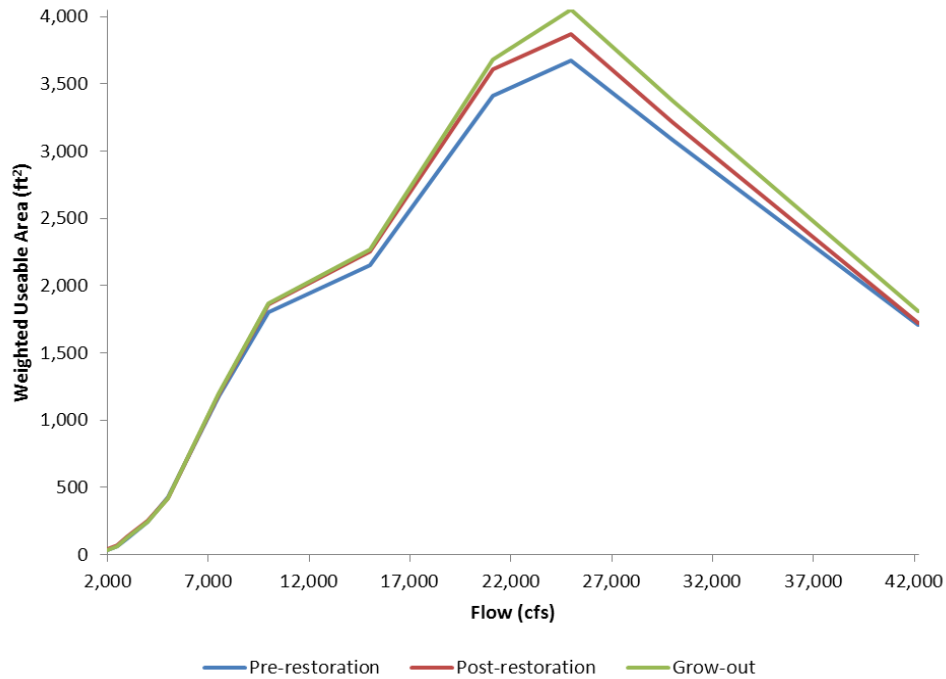


Figure 43

Hammon Bar steelhead fry rearing flow-habitat relationships before, after and at grow-out of the pilot riparian plantings

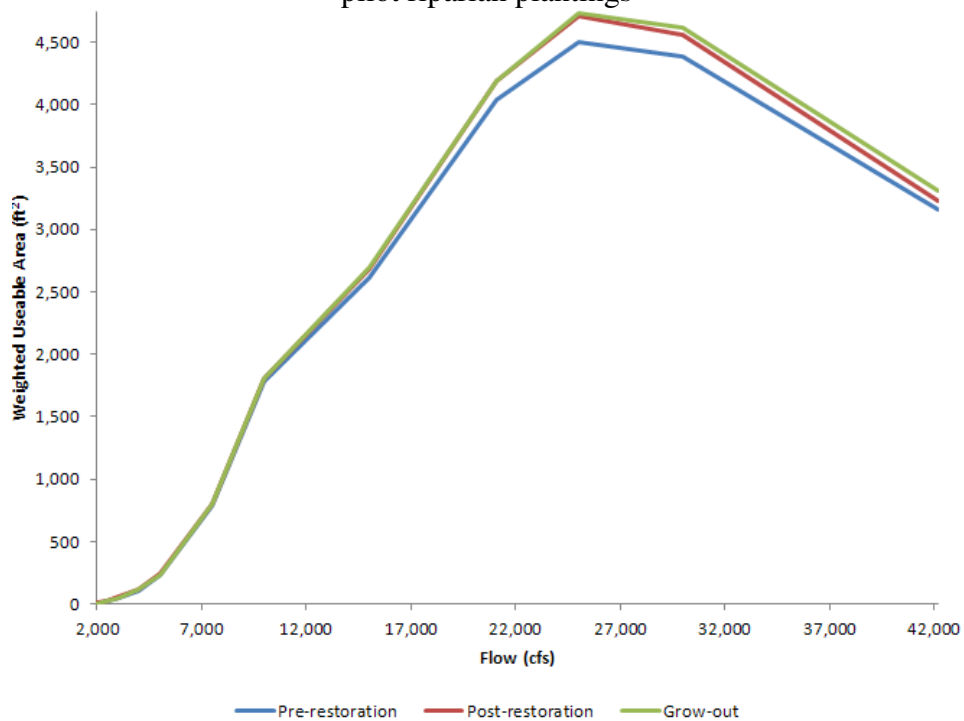


Figure 44

Hammon Bar steelhead juvenile rearing flow-habitat relationships before, after and at grow-out of the pilot riparian plantings

Discussion

The increased fry and juvenile habitat caused by the riparian plantings is a combination of reduced velocities due to increased bed roughness from the plantings and the higher habitat suitability of the woody material comprising the plantings, versus the original largely unvegetated floodplain. The limited benefit of the pilot planting reflects the relatively small area covered by the plantings, relative to the entire area of the restoration site. The plantings show little to no benefit until flows reach 10,000 cfs, reflecting the relatively high elevations at which the pilot plantings were made. The plantings show the greatest benefit for fall-run Chinook salmon fry rearing habitat, reflecting the lower velocity preference for fry, versus juvenile, and the lower preference for non-woody cover, versus steelhead.

Yuba River Daguerre Alley Restoration Project Monitoring

Methods

In FY 2013, we began to collect topography, cover and substrate data for the Daguerre Alley restoration project, using RTK GPS units for dry and shallow areas, and a combination of ADCP and RTK GPS for deep areas, using the same methods described above for the American River. We were not able to complete this data collection in FY 2013 due to equipment problems. We plan to complete our data collection in early FY 2014. We also installed pressure transducers at the upstream and downstream end of the Daguerre Alley project to determine if the stage-discharge relationships at these locations had changed since the data was collected to develop Greg Pasternack's entire river model.

Results

Following completion of data collection in FY 2014, we will be developing a two-dimensional hydraulic and habitat model of the Daguerre Alley site, using the same methods described above for the Hammon Bar project. Since the Daguerre Alley project is a side-channel project, we will use output from Greg Pasternack's entire river model to determine the inflow boundary condition for the model. We will be simulating habitat over a range of flows for both pre-project conditions and for a potential alternative project where flows would be released from the Hallwood-Cordua canal to a location near the upstream end of the Daguerre Alley site. Results will be presented in the FY 2014 annual report.

Cottonwood Creek Baseline Habitat Assessment

Methods

The purpose of this investigation is to collect PHABSIM data on transects previously established by Graham Matthew and Associates (2003), with the resulting PHABSIM transects to be used to quantify the baseline amount of fry and juvenile fall-run Chinook salmon and steelhead/rainbow trout rearing habitat in Cottonwood Creek. The baseline amount of habitat will be used to

determine how much habitat will need to be restored in Cottonwood Creek to achieve the doubling goals of AFRP for Cottonwood Creek. Graham Matthews and Associates had 12 transects on Cottonwood Creek downstream of South Fork Cottonwood Creek, nine transects on Cottonwood Creek upstream of South Fork Cottonwood Creek, and two transects on South Fork Cottonwood Creek. We sent letters to the landowners of the properties where the transects were located to get permission for access. We were able to get permission for access for 11 of Graham Matthews' transects on Cottonwood Creek downstream of South Fork Cottonwood Creek, three transects on Cottonwood Creek upstream of South Fork Cottonwood Creek, and both transects on South Fork Cottonwood Creek, for a total of 16 transects¹¹. In FY 2013, we used the mesohabitat mapping described in the following page to randomly select an additional six PHABSIM transects on Cottonwood Creek upstream of South Fork Cottonwood Creek and seven transects on South Fork Cottonwood Creek. The transect locations are shown in Figure 45.

For those transects where we got permission for access, we collected the PHABSIM transect data described for the American River, using the same methods, with the following exceptions: 1) all verticals were spaced two feet apart, to allow for the use of an adjacent velocity criteria; and 2) no substrate data were collected, since the parameters used to simulate rearing habitat are depth, velocity, cover¹² and adjacent velocity. Headpins and tailpins were marked on each bank above the 4,400 cfs water surface level for Cottonwood Creek downstream of South Fork Cottonwood Creek, the 2,600 cfs water surface level for Cottonwood Creek upstream of South Fork Cottonwood Creek, and the 1,250 cfs water surface level for South Fork Cottonwood Creek¹³.

On April 30 to May 2, 2012, we conducted mesohabitat mapping for Cottonwood Creek from the confluence of the Middle and North Forks of Cottonwood Creek to the Sacramento River, and for South Fork Cottonwood Creek from Bowman Road to the confluence of South Fork Cottonwood Creek with Cottonwood Creek, marking the ends of each mesohabitat unit with a Garmin GPS unit. Cottonwood Creek was mapped via jetboat, while South Fork Cottonwood Creek was mapped by floating the reach. We had access to the entire length of stream. The GPS data was put in GIS to make polyline shapefiles of the mesohabitat units, which were then used to calculate the length of each mesohabitat unit. The mesohabitat types used and their definitions are given in Table 3. The mesohabitat maps were used to extrapolate from the PHABSIM transects to all of Cottonwood Creek.

¹¹ These transects were also used for the Cottonwood Creek Geomorphic Monitoring task.

¹² As shown in Table 2, our cover coding system takes into account the cover value of cobble (cover code 1) and boulder (cover code 2) sized substrates.

¹³ These were the highest flows simulated. Pins were installed above these flows so that the entire wetted channel could be modeled at the highest simulated flow. We do not know if these flows are less than or greater than bankfull flows.

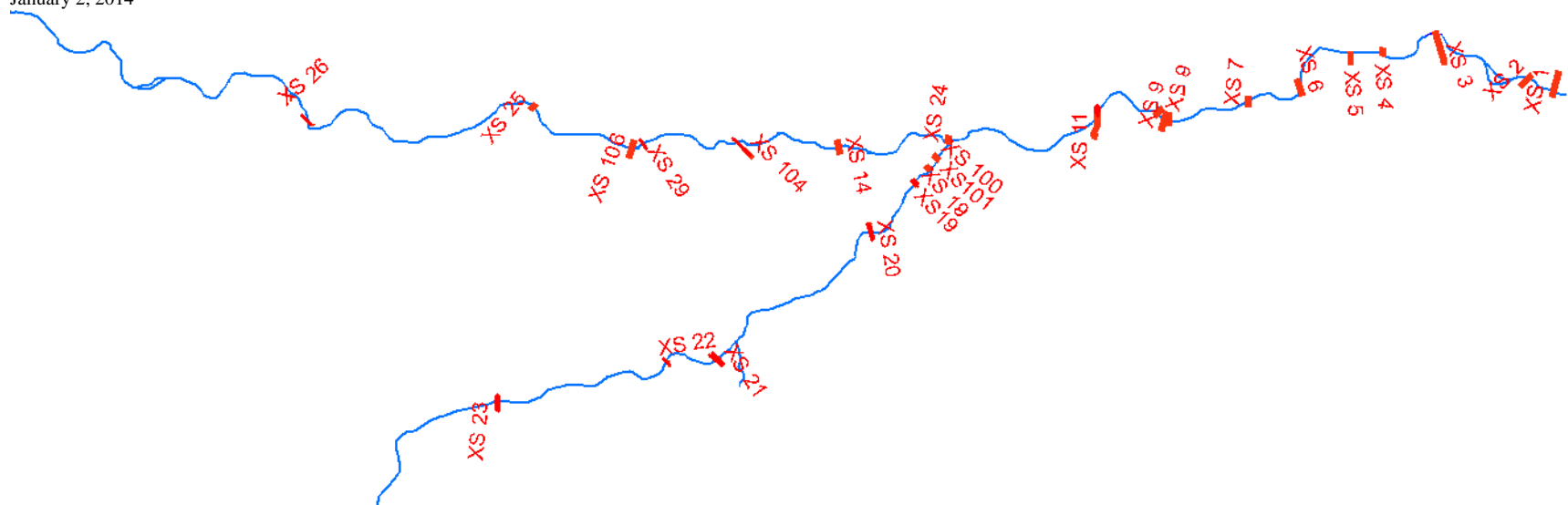


Figure 45
Cottonwood Creek Baseline Habitat Assessment transect locations

Table 3. Mesohabitat type definitions.

Habitat Type	Definition
Pool	Primary determinant is downstream control - thalweg gets deeper as go upstream from bottom of pool. Fine and uniform substrate, below average water velocity, above average depth, tranquil water surface. Depth is not used to determine whether a mesohabitat unit is a pool.
Glide	Primary determinants are no turbulence (surface smooth, slow and laminar) and no downstream control. Low gradient, substrate uniform across channel width and composed of small gravel and/or sand/silt, depth below average and similar across channel width, below average water velocities, width of channel tends to spread out, thalweg has relatively uniform slope going downstream.
Run	Primary determinants are moderately turbulent and average depth. Moderate gradient, substrate a mix of particle sizes and composed of small cobble and gravel, with some large cobble and boulders, above average water velocities, usually slight gradient change from top to bottom, thalweg has relatively uniform slope going downstream.
Riffle	Primary determinants are high gradient and turbulence. Below average depth, above average velocity, thalweg has relatively uniform slope going downstream, substrate of uniform size and composed of large gravel and/or cobble, change in gradient noticeable.

Results

The results of the mesohabitat mapping are given in Table 4. In FY 2013, we completed collecting all of the data, hydraulic calibration and hydraulic and habitat simulation for all 29 transects, except for Transect 7, as discussed below. Hydraulic calibration of most transects used the *IFG4* option in PHABSIM. For five of the transects, which did not calibrate with *IFG4*, we used the *MANSQ* option in PHABSIM for hydraulic calibration. During hydraulic calibration of three of the nine original transects where we had been unable to collect all three sets of WSELs in FY 2012, we discovered that there had been significant changes in the stage-discharge relationships as a result of high flows in December 2012, when daily average flows reached 8,800 cfs. For two of these transects, we were able to discard the FY 2013 WSEL measurement, and calibrate the transects with *MANSQ* using the two sets of WSELs measured in FY 2012. However, we ended up having to throw out the remaining transect (Transect 7), which could not be calibrated with *MANSQ* due to a strong backwater effect from a downstream hydraulic control. During calibration of four of the six new transects on South Fork Cottonwood Creek, we discovered that we had missed a downstream hydraulic control during data collection. For these transects, we were still able to reasonably accurately estimate the stage of zero flow, since the lowest set of water surface elevation was collected at a very low flow (2.6 cfs). It also appeared that we had missed a downstream hydraulic control for two of the seven new transects on Cottonwood Creek upstream of South Fork Cottonwood Creek. For both transects, we needed to estimate the stage of zero flow. We concluded that the calibration of these was

Table 4. Mesohabitat composition.

Habitat Type	Glide	Pool	Riffle	Run
Cottonwood Creek downstream of SF Cottonwood Creek	24.06%	28.26%	18.79%	28.90%
Cottonwood Creek upstream of SF Cottonwood Creek	26.48%	32.69%	15.33%	25.50%
South Fork Cottonwood Creek	23.97%	20.12%	14.43%	41.48%

acceptable since in one case the calibration was not sensitive to the stage of zero flow, and in the other case, we used a stage of zero flow that was the best balance of the beta and mean error parameters in *IFG4*.

We simulated fry and juvenile fall-run Chinook salmon and steelhead/rainbow trout rearing habitat for the following flow ranges: 1) 15 to 4,400 cfs for Cottonwood Creek downstream of South Fork Cottonwood Creek; 2) 15 to 2,600 cfs for Cottonwood Creek upstream of South Fork Cottonwood Creek; and 3) 0.1 to 1,250 cfs for South Fork Cottonwood Creek. The resulting flow-habitat relationships (Figures 46 to 48) were used with the flow-frequency curves for the three reaches (Figures 49 to 51) to calculate the median (50% habitat exceedance) values for each reach, species and life stage (Table 5)¹⁴. Assuming that the amount of habitat in Table 5 produced 1,584 fall-run adults (the average from 1992 through 2010), an additional 2.724 times as much habitat (Table 6)¹⁵ would be required to reach the Cottonwood Creek doubling goal of 5,900 fall-run adults (5,900/1,584 – 1).

Discussion

The figures in Table 6 assume that physical habitat for fry and juvenile rearing is limiting the population of fall-run Chinook salmon in Cottonwood Creek. Habitat enhancement measures should focus on creating habitat with optimal conditions for fry and juvenile rearing (shallow, slow areas with woody cover). Our qualitative assessment is that woody cover is the primary limiting habitat attribute for Cottonwood Creek, since in most locations, woody cover is not inundated until relatively high flows due to channel downcutting. We did not collect data for Transect 10, which was located under the railroad tracks just upstream of I-5 since this cross-section, located in a pool, was not representative of pools in Cottonwood Creek downstream of South Fork Cottonwood Creek, and because we already had another four pool transects in Cottonwood Creek downstream of South Fork Cottonwood Creek.

¹⁴ The median habitat is not for a specific flow, but is based on the entire flow regime of Cottonwood Creek.

¹⁵ The amount of habitat in Table 6 is not for a specific flow, but is the amount of habitat needed for the hydrology of Cottonwood Creek, as shown in Figures 49 to 51.

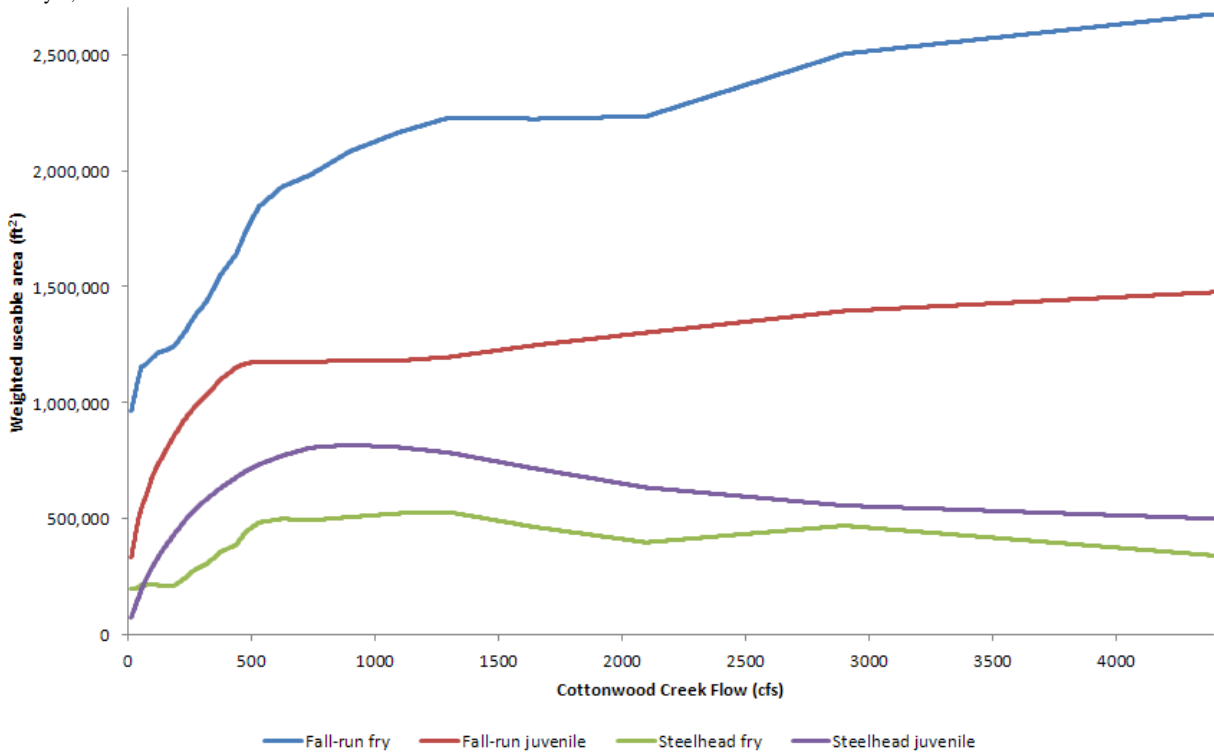


Figure 46

Cottonwood Creek (downstream of South Fork Cottonwood Creek) flow-habitat relationships

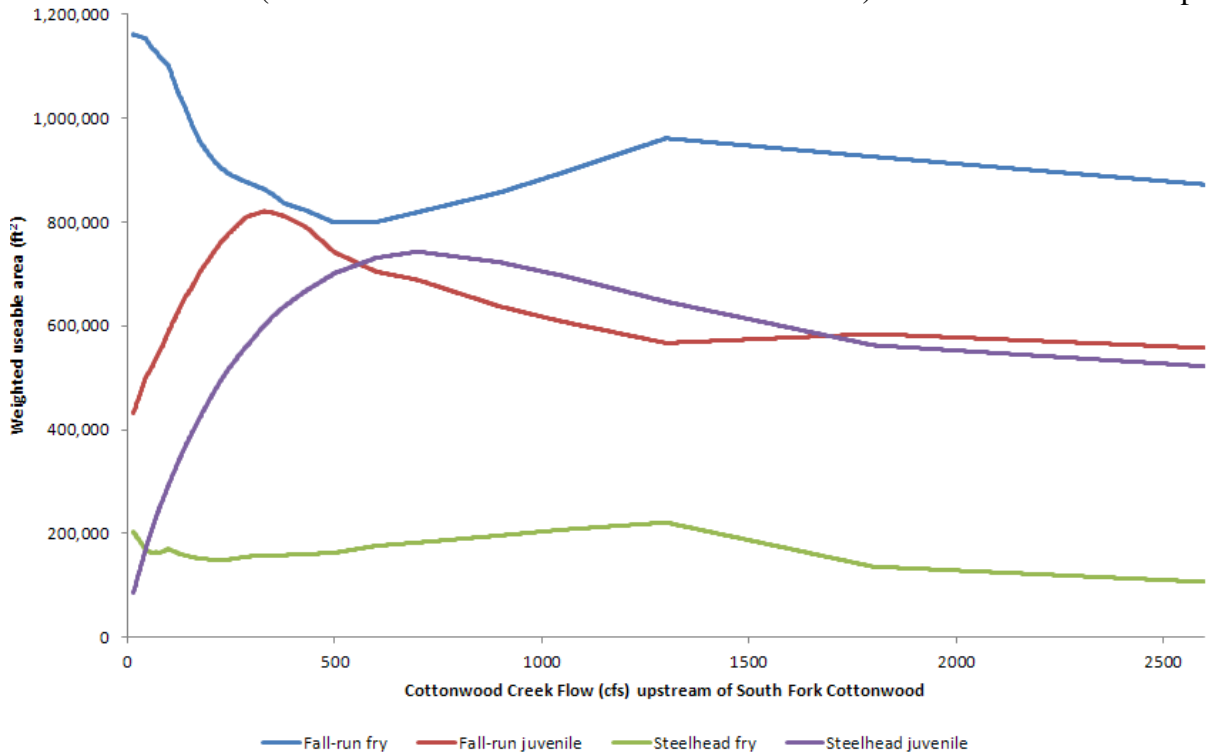


Figure 47

Cottonwood Creek (upstream of South Fork Cottonwood Creek) flow-habitat relationships

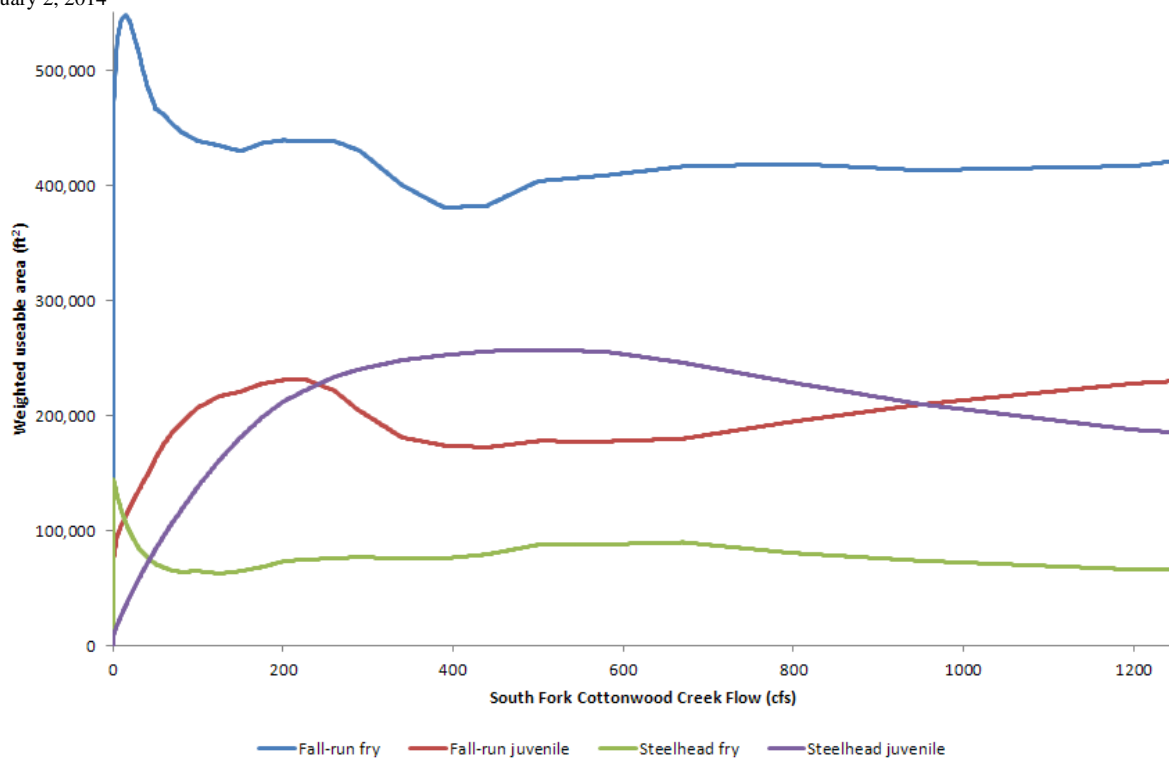


Figure 48
South Fork Cottonwood Creek flow-habitat relationships

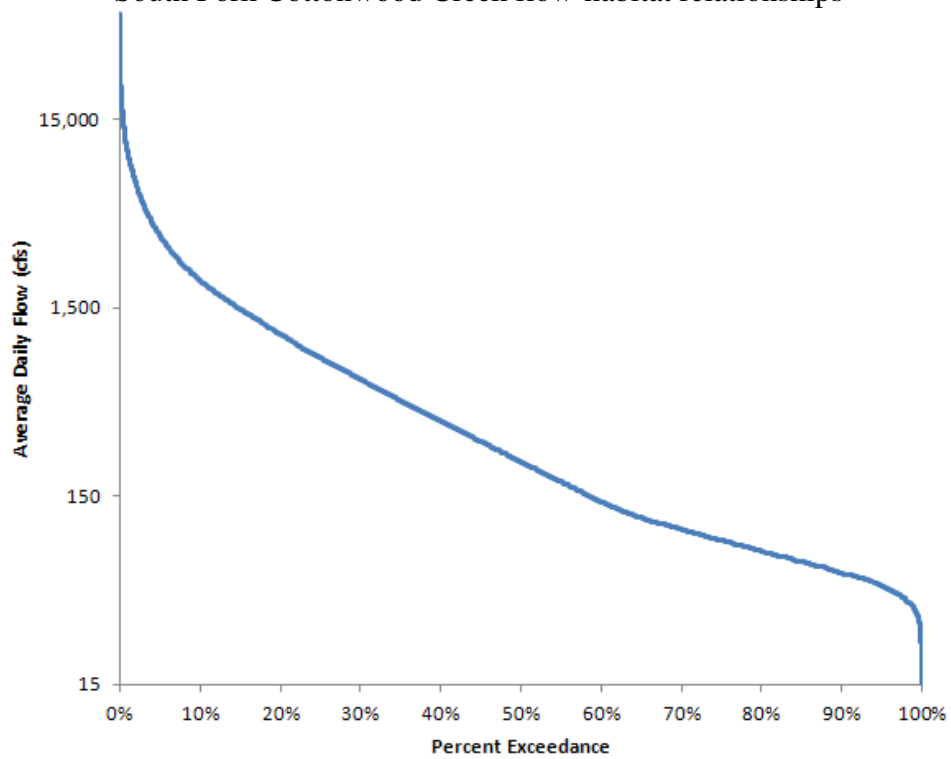


Figure 49
Cottonwood Creek (downstream of South Fork Cottonwood Creek) flow-frequency curve

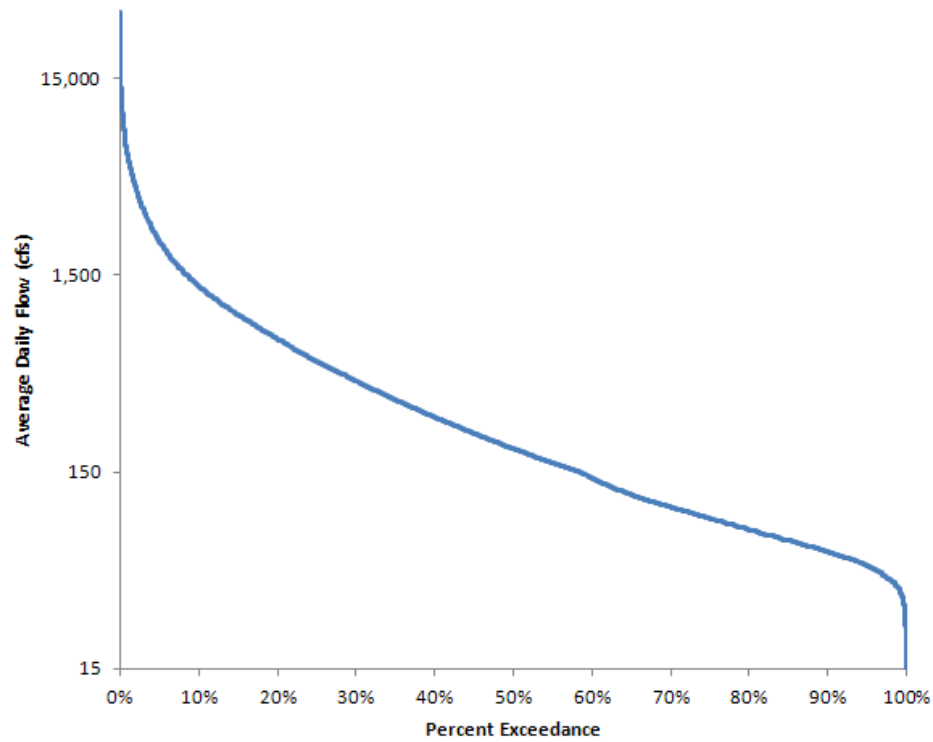


Figure 50

Cottonwood Creek (upstream of South Fork Cottonwood Creek) flow-frequency curve

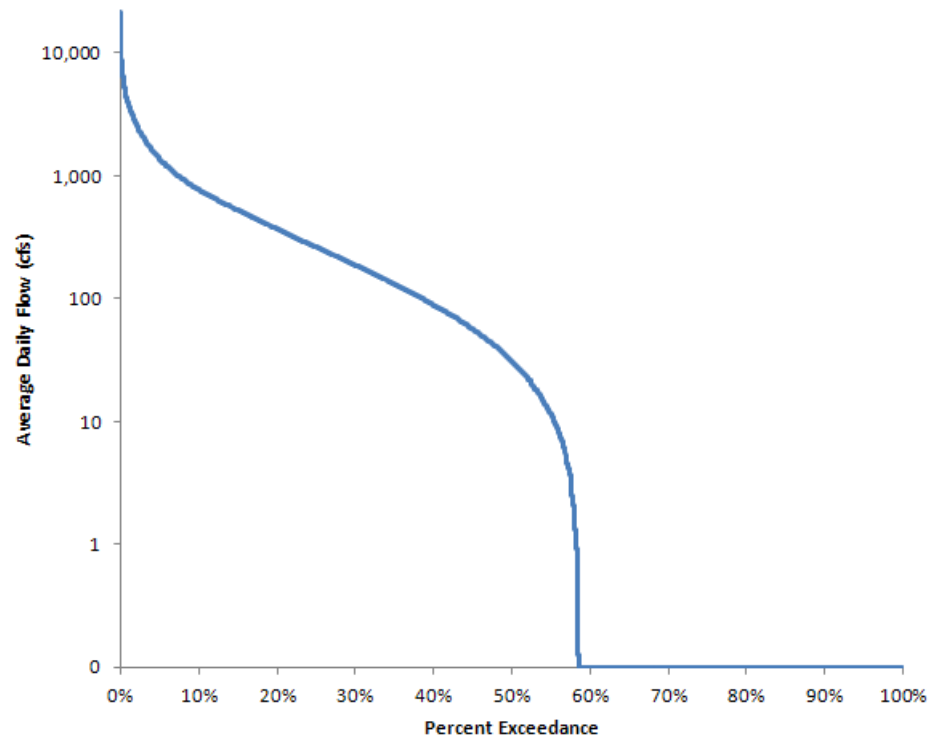


Figure 51

South Fork Cottonwood Creek flow-frequency curve

Table 5. Median Habitat Values (ft²)

Species/Life Stage	Fall-run Chinook salmon		Steelhead	
	Fry	Juvenile	Fry	Juvenile
Cottonwood Creek downstream of SF Cottonwood Creek	1,271,496	891,746	227,140	460,783
Cottonwood Creek upstream of SF Cottonwood Creek	954,238	628,303	163,442	436,482
South Fork Cottonwood Creek	403,673	119,175	64,594	41,634

Table 6. Amount of Habitat Restoration Needed to Double Populations (ft²)

Species/Life Stage	Fall-run Chinook salmon		Steelhead	
	Fry	Juvenile	Fry	Juvenile
Cottonwood Creek downstream of SF Cottonwood Creek	3,463,555	2,429,116	618,729	1,255,173
Cottonwood Creek upstream of SF Cottonwood Creek	2,599,344	1,711,497	445,216	1,188,977
South Fork Cottonwood Creek	1,099,605	324,633	175,954	113,411

Cottonwood Creek Geomorphic Monitoring

Methods

On August 28-31, 2012, the bed profile of five of the PHABSIM transects was extended beyond the headpins and tailpins, to the original ends of Graham Matthews and Associates (2003) transects, using our survey-grade RTK GPS. We transmitted this data to Graham Matthews and Associates for their use to assess changes in cross-sectional profiles since their data was collected. The number of transects sampled was limited by the length of time required to float Cottonwood Creek due to low flow conditions and the distance at which we were able to receive a radio signal from our RTK GPS base unit.

Results

Our monitoring will allow for a comparison of channel changes for the entire extent of five of the sixteen transects, and for the lower-flow portion of the remaining 11 transects, using data from our PHABSIM data collection¹⁶. Results are given in Figures 52 to 63. Results are not given for transects 1, 3 or 106 since we were unable to tie the vertical elevations for these transects into North American Vertical Datum 1988 due to the distance of these transects from vertical control. We were unable to survey the entire length of Transect 11 due to heavy brush. This transect had shown the greatest change, with the existing wetted channel (which we were able to survey) located past the end of Graham Matthews and Associates (2003) transect, while

¹⁶ These are some of the transects that were used for the Cottonwood Creek Baseline Habitat Assessment task. Only the bed elevation data was used for this task, since that was the only data that had been collected by Graham Matthews for these transects.

the thalweg of Graham Matthews and Associates (2003) transect (the portion of the transect that could not be surveyed due to heavy brush) is now in an off-channel area, and was inundated during data collection.

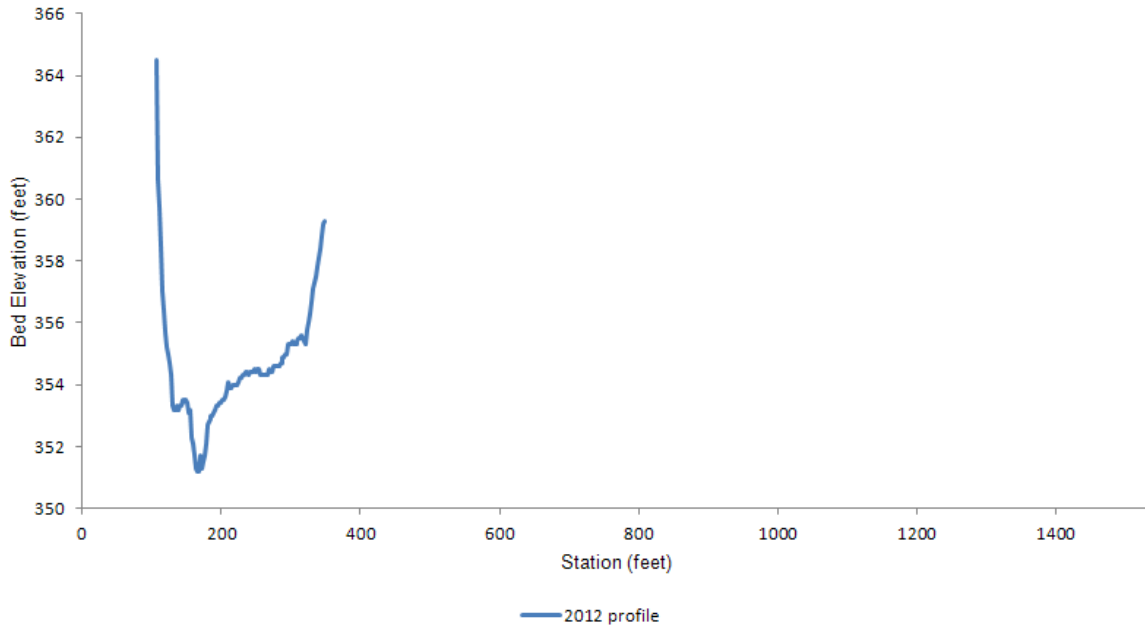


Figure 52
Cottonwood Creek Transect 2 2012 Cross-sectional Bed Profile

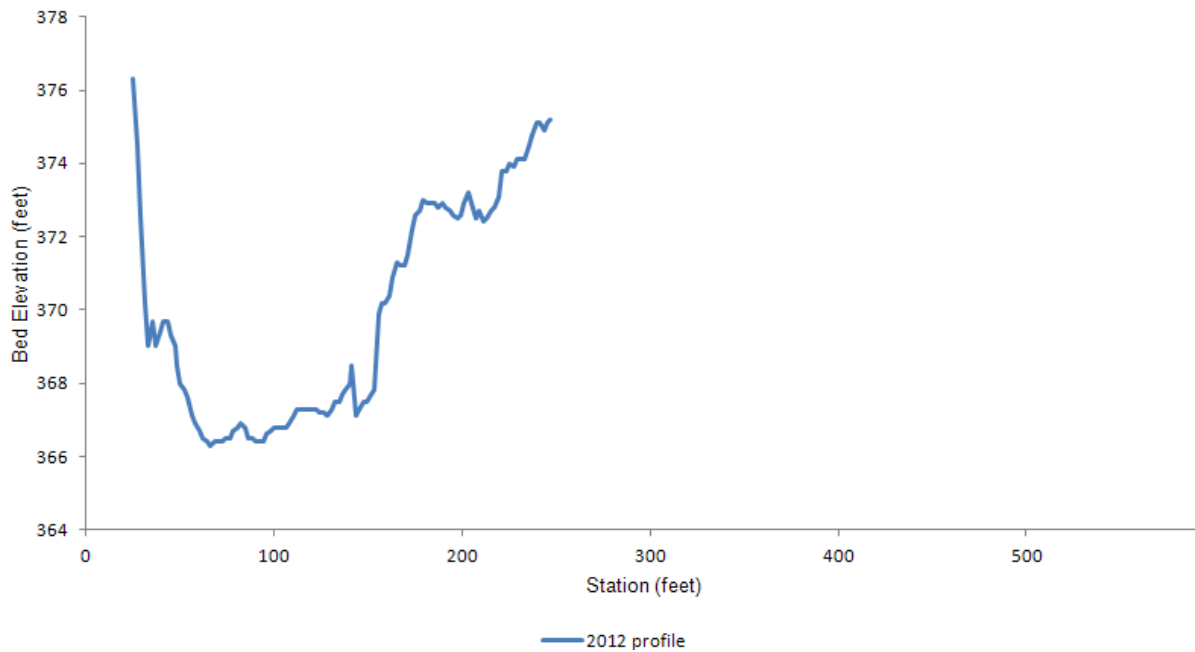


Figure 53
Cottonwood Creek Transect 4 2012 Cross-sectional Bed Profile

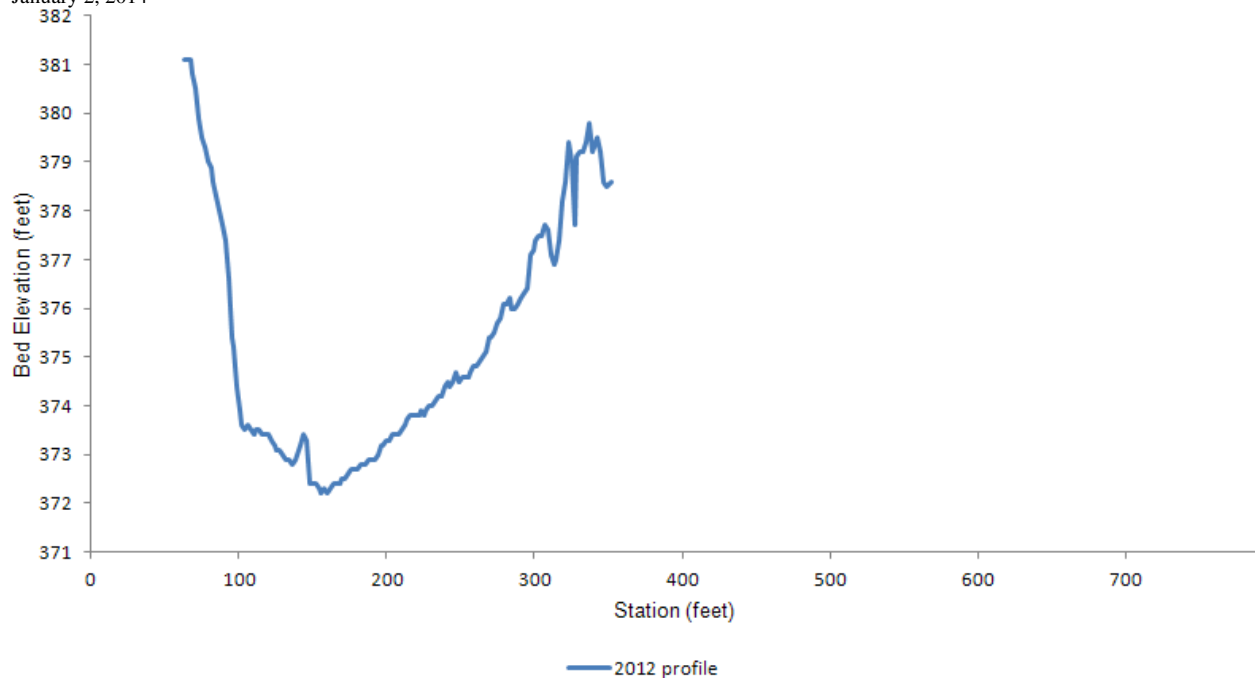


Figure 54
Cottonwood Creek Transect 5 2012 Cross-sectional Bed Profile

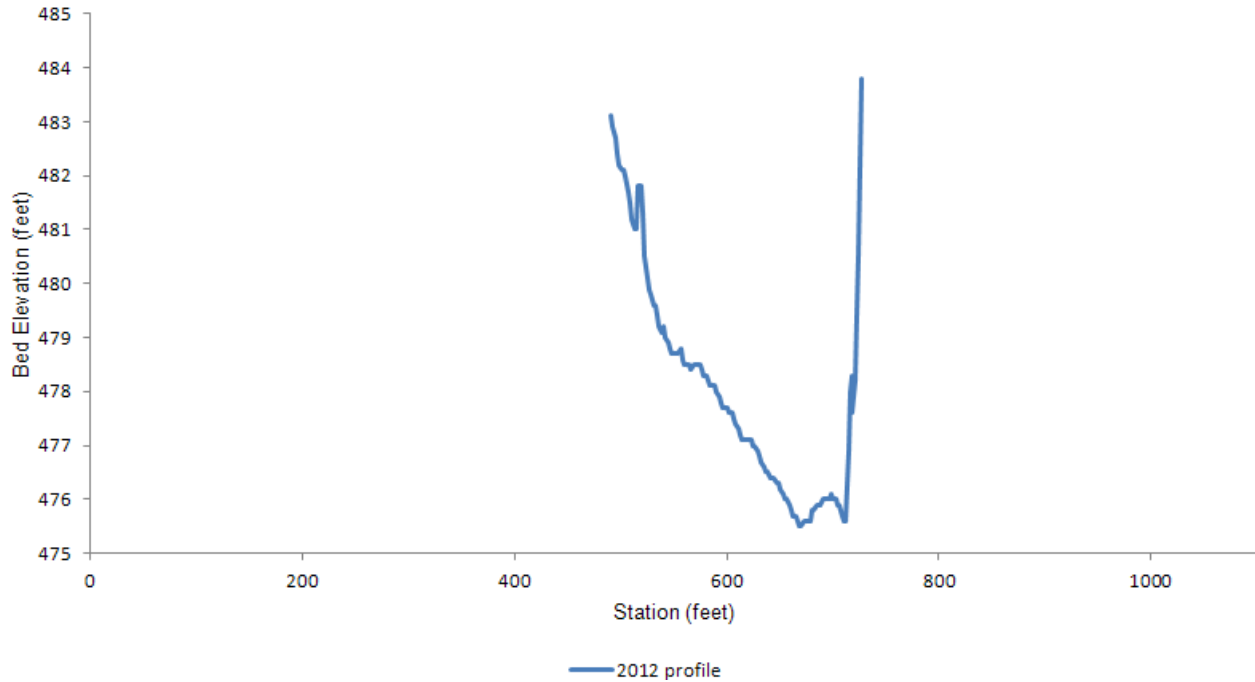


Figure 55
Cottonwood Creek Transect 6 2012 Cross-sectional Bed Profile

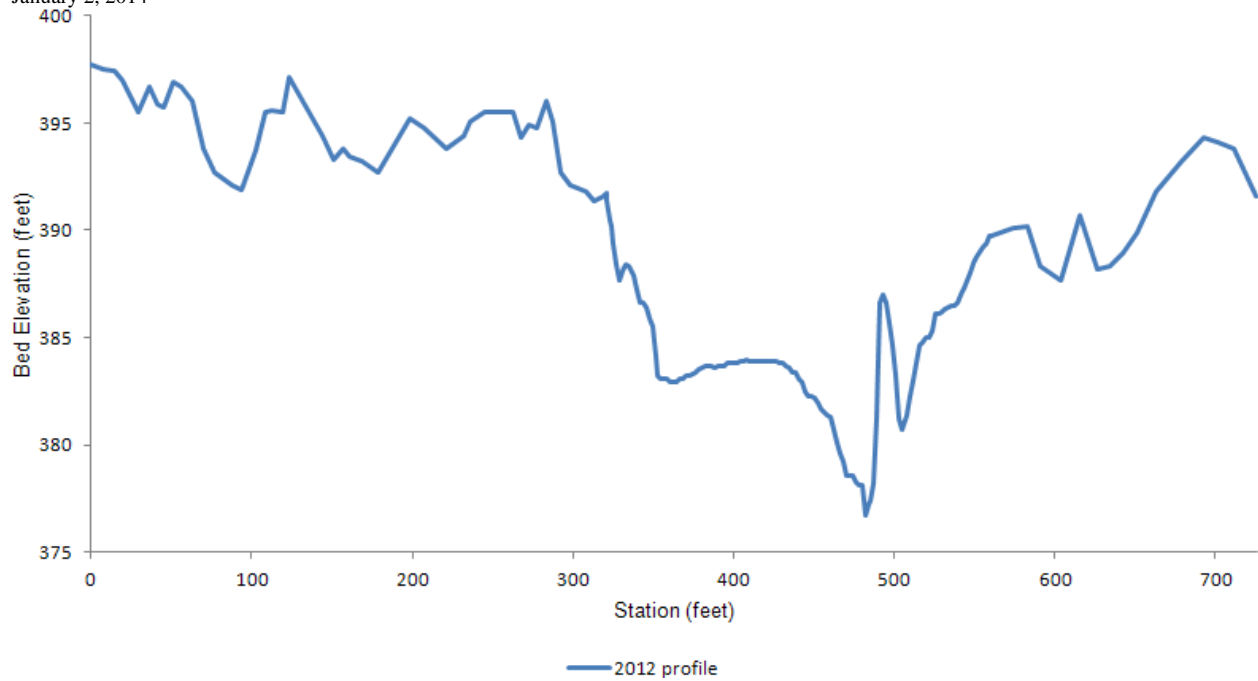


Figure 56
Cottonwood Creek Transect 7 2012 Cross-sectional Bed Profile

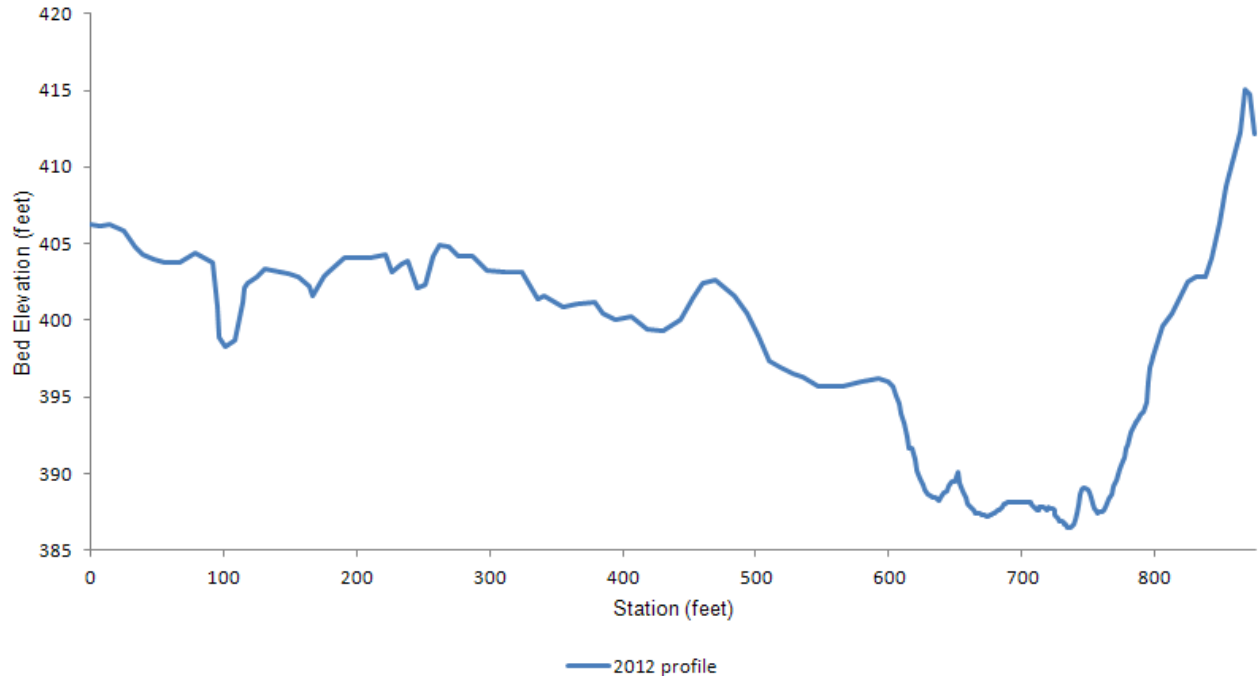


Figure 57
Cottonwood Creek Transect 8 2012 Cross-sectional Bed Profile

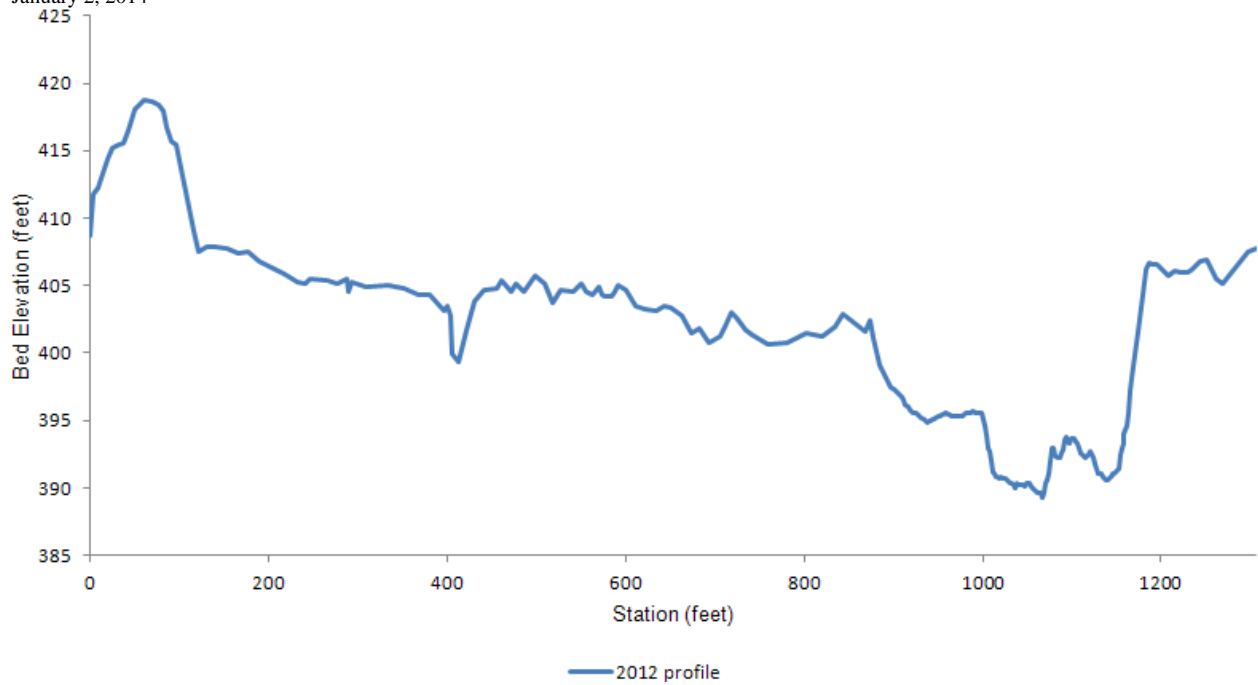


Figure 58
 Cottonwood Creek Transect 9 2012 Cross-sectional Bed Profile

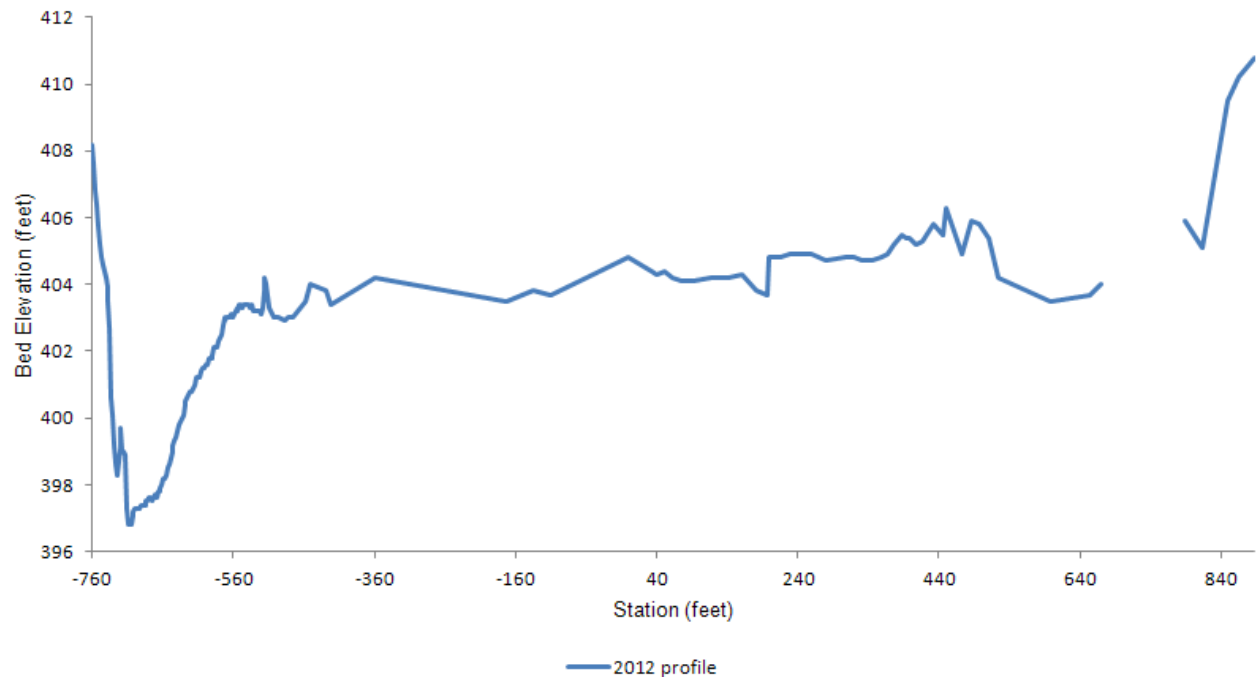


Figure 59
 Cottonwood Creek Transect 11 2012 Cross-sectional Bed Profile

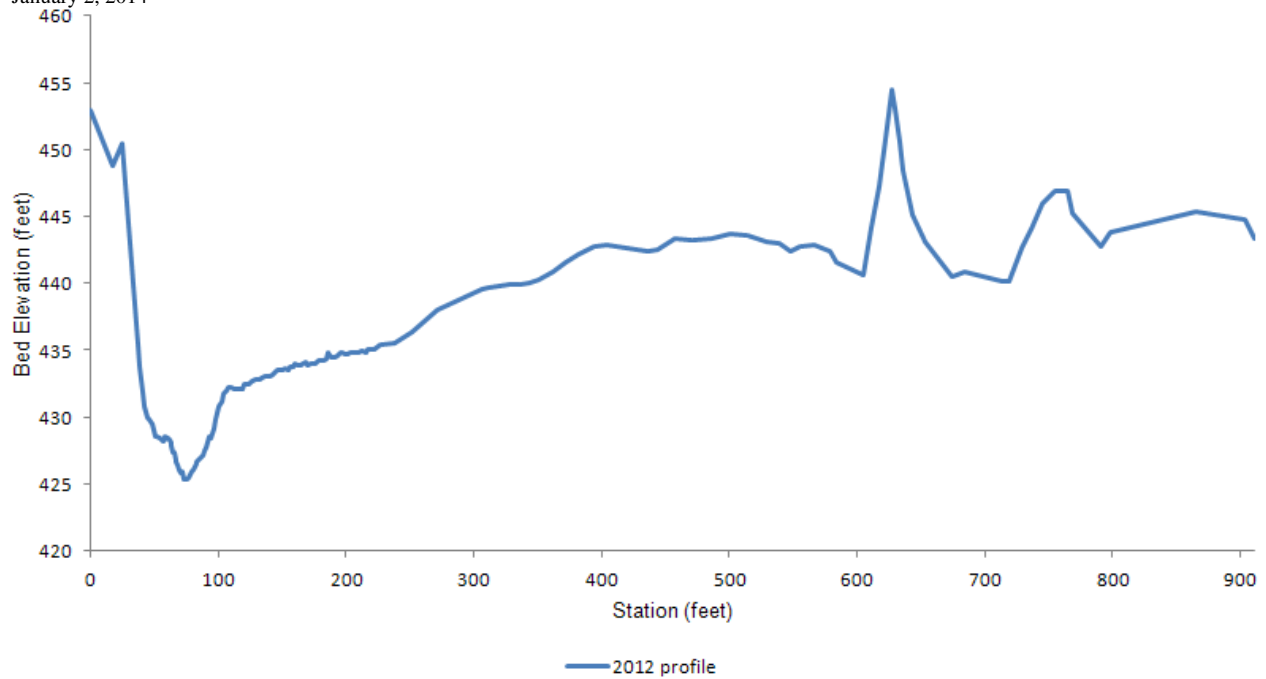


Figure 60
Cottonwood Creek Transect 14 2012 Cross-sectional Bed Profile

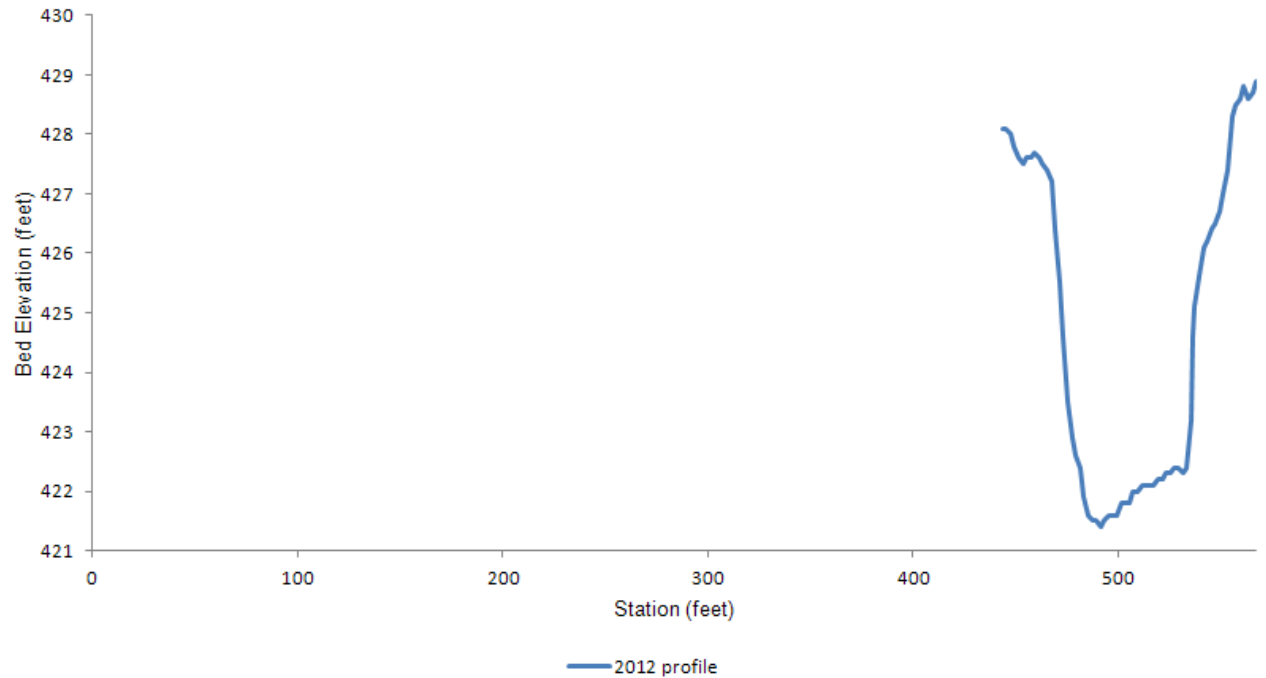


Figure 61
Cottonwood Creek Transect 100 2012 Cross-sectional Bed Profile

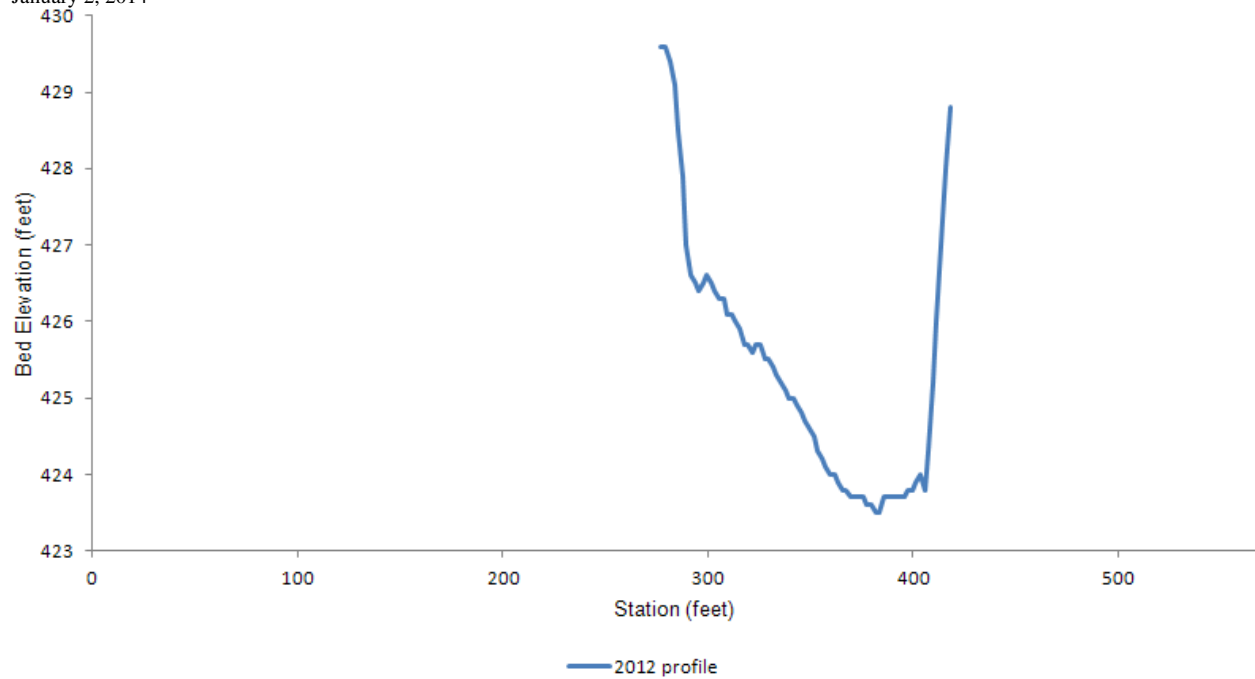


Figure 62
Cottonwood Creek Transect 101 2012 Cross-sectional Bed Profile

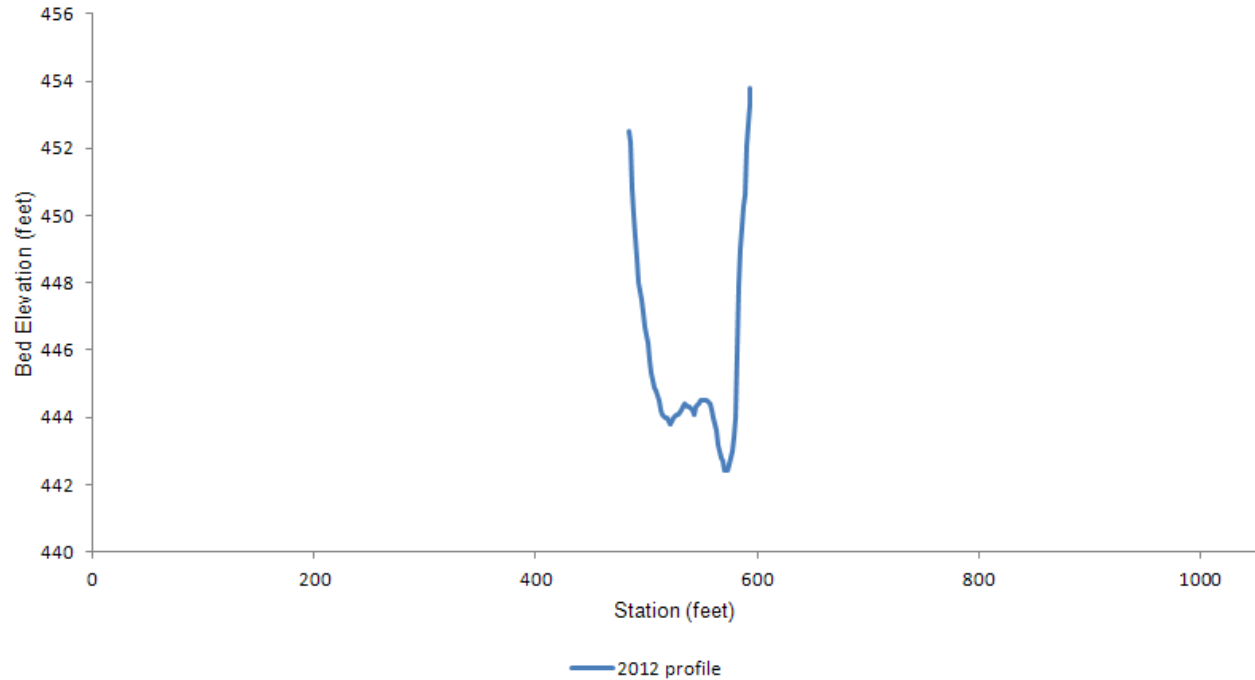


Figure 63
Cottonwood Creek Transect 104 2012 Cross-sectional Bed Profile

Antelope Creek Geomorphic Monitoring

Methods

Lower Antelope Creek is a distributary system, with flow splitting into Craig, Antelope, and New Creeks and Butler Slough. Stillwater Sciences et al. (2011) identified the nature of the flow splits as a critical piece of information that would be needed to assess upstream fish passage in Lower Antelope Creek. The first flow split, going downstream, is into Craig and Antelope Creeks (Figure 64). The purpose of this investigation was to develop a hydraulic model to determine the flow splits, over a range of Antelope Creek flows. The hydraulic model has two inflow boundaries (from Antelope and Little Antelope Creeks) and three outflow boundaries (to Craig and Antelope Creeks and an overflow channel). Data were collected using the same methods given above for the dry and shallow portions of the American River gravel sites.

Results

Data collection was completed in FY 2012. Flows and water surface elevations were measured for all five boundaries at three different flows. Hydraulic modeling was conducted during FY 2013 using the same methods given above for the American River, with the exception of the two-dimensional model having two inflow boundaries and three outflow boundaries. We simulated the flow split for Antelope Creek flows of 10 to 150 cfs, by 10 cfs increments. Little Antelope Creek flows were calculated by linear interpolation between the flows in Table 7. Under all simulated flow conditions, most of the Antelope Creek flows go down Craig Creek (Figure 65).

Discussion

Based on the results of this modeling, upstream passage assessment should focus on critical riffles in Craig Creek, since Craig Creek is the most likely path for upstream migrant spring-run Chinook salmon. Further investigations could include simulating flow splits at flows greater than 150 cfs. Such work would answer questions such as: 1) at what flows is there a 50/50 split between Craig and Antelope Creek flows; 2) whether the trajectory of the flow split at 150 cfs continues at higher flows or whether the Craig and Antelope Creek flows keep moving towards each other at higher flows; and 3) what is the flow split at 553 cfs (the highest measured flow in Antelope Creek). Answers to these questions could be of value in looking at steelhead upstream migration, which could be at higher flows than for spring-run Chinook salmon.

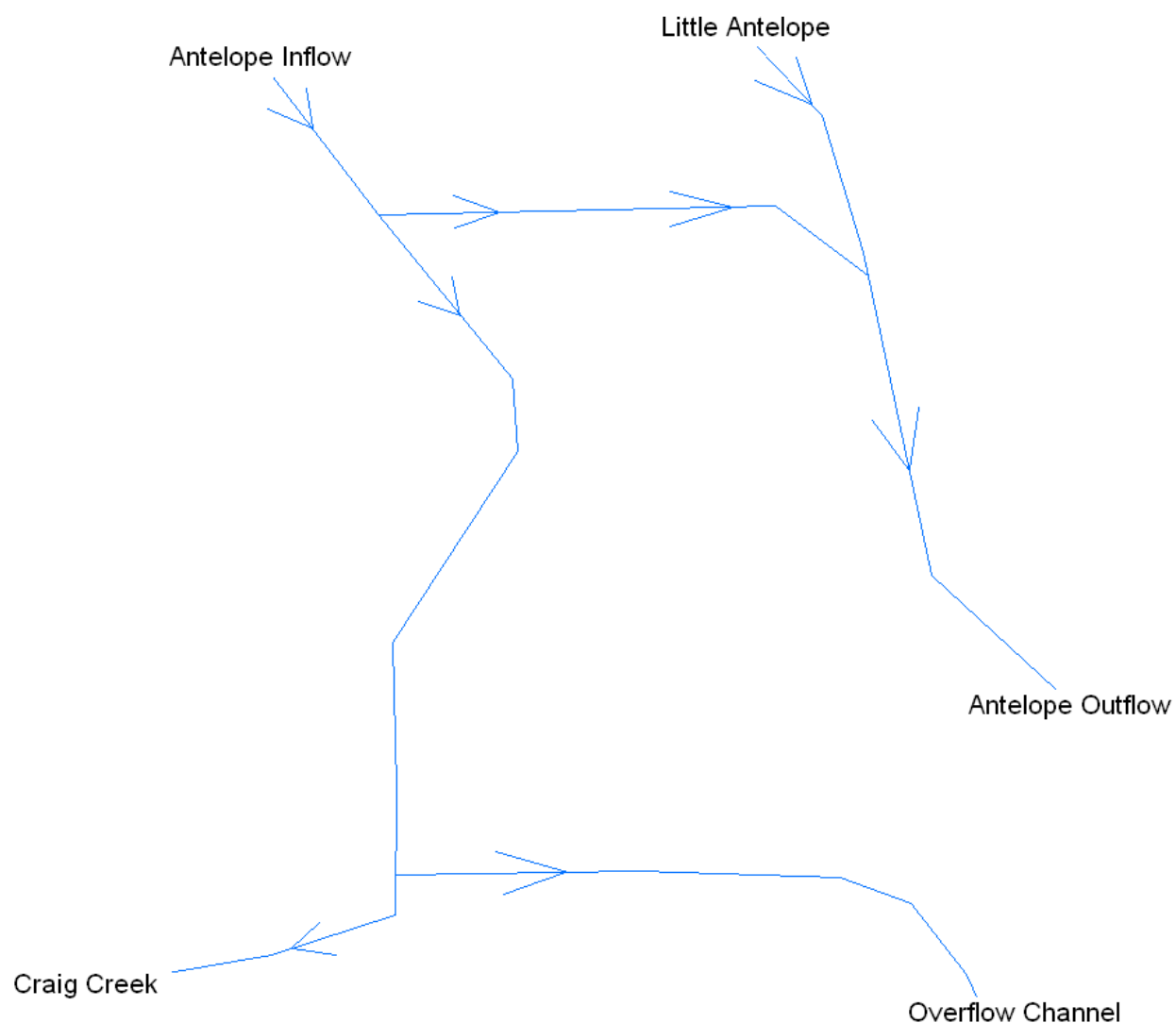


Figure 64
Antelope Creek Flow Split Study Area

Table 7. Measured Antelope and Little Antelope Creek Flow (cfs)

Sampling Date	Antelope Creek	Little Antelope Creek
12/3/12	553	34.1
4/16-17/12	148.32	22.61
1/8/13	71.2	7.51
5/14/12	56.01	0.02
7/10/12	1.26	0

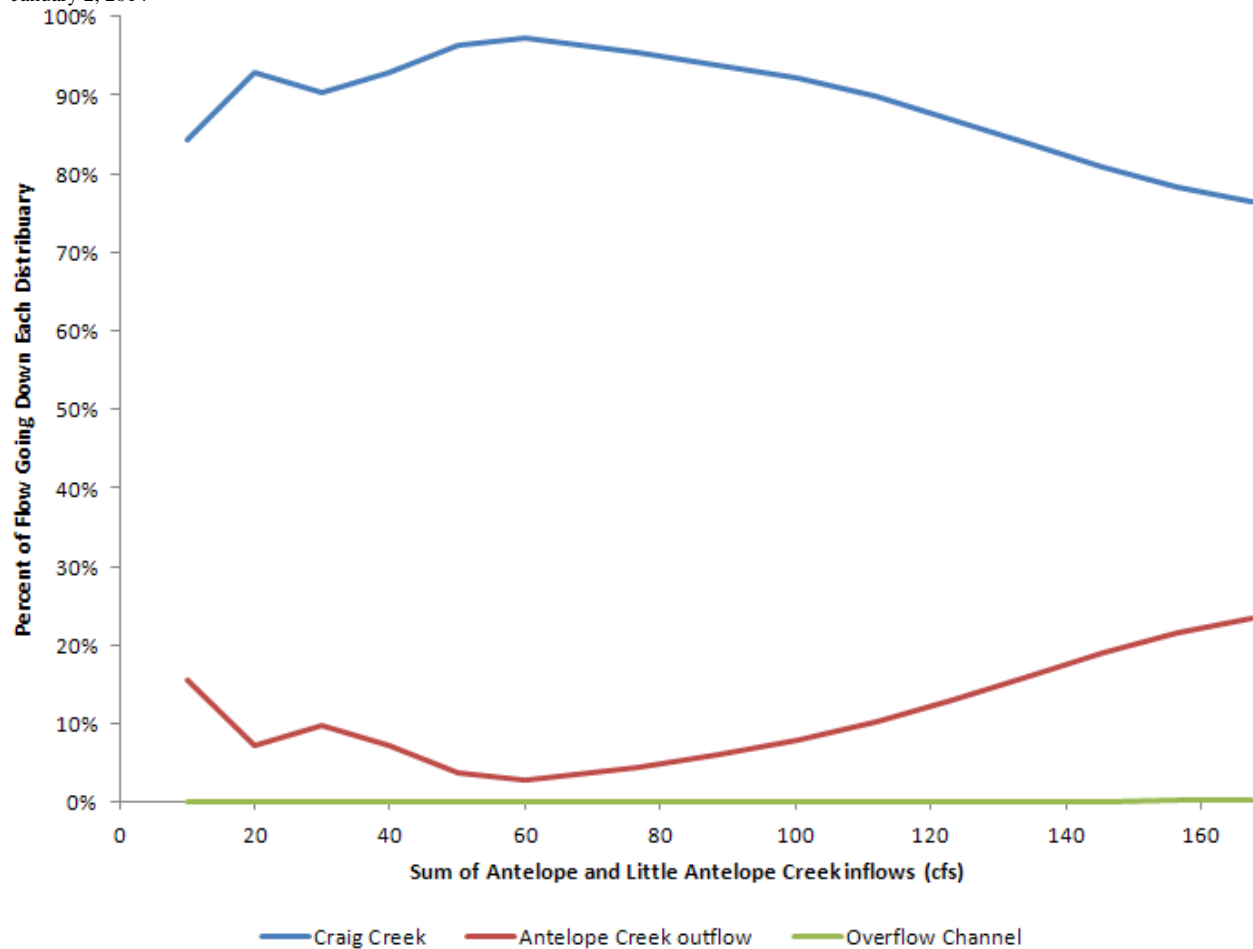


Figure 65
Antelope Creek Flow Splits

Antelope Creek Bridge As-Built Survey

Methods

The purpose of this investigation was to conduct an as-built survey of the topography of Antelope Creek in the vicinity of the Antelope Creek Bridge restoration project immediately following the completion of construction of this project. We used our survey grade RTK GPS units and total station to collect topography data on November 26-29, 2012.

Results

We collected a total of 3,235 topographic data points. The as-built topography is shown in Figure 66. We will be resurveying this site in FY 2014 to document the effect on the channel topography of high flows in December 2012.

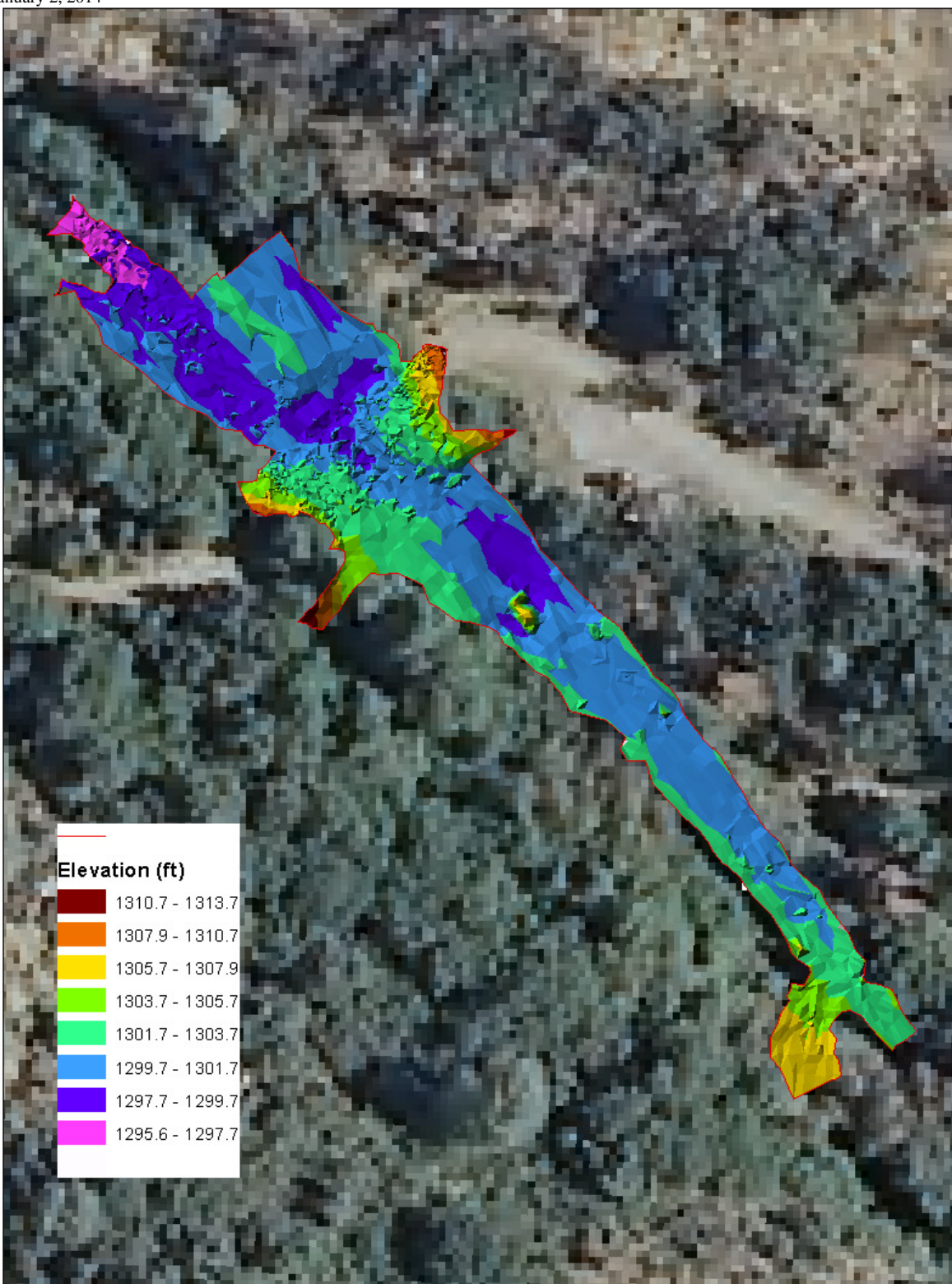


Figure 66
Antelope Creek Bridge Site As-Built Topography

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